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USER'S MANUAL FOR ILSLOC: SIMULATION FOR DEROGATION EFFECTS ON THE LOCALIZER PORTION OF THE INSTRUMENT LANDING SYSTEM

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16. Abstract

This manual presents the complete ILSLOC computer program package. In addition to including a thorough description of the program itself and a commented listing, the manual contains a brief description of the ILS system and antenna patterns. To illustrate the program a test case was created and the figures of the case are incorporated in the report. Program DYNM and program ILSPLT are included as Appendices. The ILSPLT, complete with sample graphs, is a plotting routine for ILSLOC.

For a technical mathematical analysis of the system, the FAA report "Instrument Landing System Scattering" No. FAA-RD-72-137 should be consulted.

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PREFACE

As part of the ILS Performance Prediction program (PPA No. FA307), a first phase ILS Localizer performance prediction computer program package has been prepared. This package consists of the computer program and the present document which describes the capabilities and limitations of the computer model as well as the step by step running of the computer program.

The computer program is intended as an aid in predicting the performance of different ILS Localizer antenna candidates for a proposed runway instrumentation or for the upgrading of an already instrumented runway. It is also intended to provide a relatively inexpensive means by which the effect of any proposed changes to an airport environment (addition of terminal buildings, hangars, etc.) on ILS performance may be predicted.

This document was prepared for TSC by D. Newsom assigned full time as a programmer to the ILS Performance Prediction program and by A. Watson who helped in its writing. The document and attached computer program are based on the theories and analyses developed by the TSC group (Chin, Jordan, Kahn and Morin) for the ILS program sponsored by H. Butts of the Systems Research and Development Service of the FAA.

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1. DEFINITION OF INSTRUMENT LANDING SYSTEM

The ILSLOC program has been written to simulate certain airport conditions which affect the localizer portion of the Instrument Landing System. The ILS is used to provide signals for the safe navigation of landing aircraft during periods of low cloud cover and other conditions of restricted visual range. Separate systems are used to communicate vertical and horizontal information; the horizontal system is called the "localizer".

This system operates by the transmission of an RF carrier, amplitude modulated by two audio frequencies, beamed to approaching airborne receivers. In an instrumented aircraft, the localizer receiver serves to demodulate the RF signal, amplify and isolate the corresponding audio signals and derive a signal to drive the ILS horizontal display in the cockpit. The pilot, by reading the display, can determine if he is on course, to the left of the runway, or the right of the runway. These signals must be strong enough to cover a radius of twenty-five miles around the antenna.

The directional information is determined by the relative strengths of the transmitted sideband signals. The audio frequency modulations, which are fixed at 90 H and 150 Hz, are radiated in different angular patterns with respect to the runway centerline extended. The "course" is defined as the locus of points where the amplitudes of the two modulations are equal. The display of a difference of the amplitudes (90 Hz and 150 Hz) of the sidebands is referred to as the Course Deviation Indication. Thus, the CDI is the pilot's indication as to what his bearing is relative to the center line of the runway. The CDI is measured in microamps. The actual course generated by any particular ILS installation will deviate from the ideal due to the interference of spurious reflections from buildings present in the range of the transmitting antenna. The deviation, caused by these buildings, or scatterers of the CDI from what the receiver should read ideally at that point in space (e.g., on the center of the runway and CDI reading other than 0) is the derogation effect.

The Localizer system transmits an asymmetrical pattern by beaming a "carrier plus sideband" pattern and a "sideband only" pattern, the composite of which gives the desired effect. If a specific localizer system uses two antenna arrays, four sets of signals will be transmitted; if the system uses a single antenna array, two sets will be transmitted.

2. ANTENNA PATTERNS

The proper angular variation of the transmitted 90 Hz and the 150 Hz modulation is achieved by the radiation of two independent sideband patterns by the transmitting antenna arrays. Equal magnitudes of 90 Hz and 150 Hz modulation are transmitted in each of these patterns, however with different relative phases. One of the patterns is symmetrical with respect to the prescribed course. An unmodulated carrier wave is transmitted with the same pattern and the combination is commonly referred to as the "carrier plus sidebands" (C + S) signal. The other signal is transmitted in an "anti-symmetrical" pattern and is referred to as the "sidebands-only" signal.

Figure 1 illustrates how these features are used to obtain the desired directional CDI. The magnitudes of the C + S and SO sideband patterns as functions of angu ar deviation from the course are illustrated in Figures 1a. The sideband amplitude of the C + S pattern represents 20% modulation of the carrier wave (or a "depth of modulation" of 0.2) at both 90 Hz and 150 Hz. Considering the phases of both modulations of the C + S signal to be positive, the relative phases and typical amplitudes of the two SO modulations are as shown in Figures 1b. The resultant 90 Hz and 150 Hz modulation patterns in the total ILS signal are obtained by algebraically combining the respective C + S and SO sideband patterns (Figures 1c). The evident consequence is that the depth of modulation is greater for 90Hz than for 150 Hz to the left of the course as seen from an approaching aircraft, and the opposite is true to the right of the course. This difference when properly calibrated in relation to the total modulation (90 Hz + 150 Hz) reaching the aircraft receiver gives the CDI as appears in Figure 1d.

Since the strength of C + S and SO signals fall off at the same rate with distance from the transmitting antenna, the CDI is independent of range.

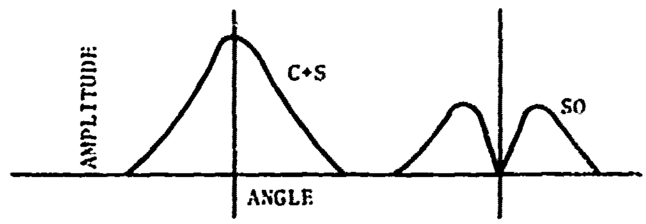


Figure 1a Sideband Pattern Magnitude

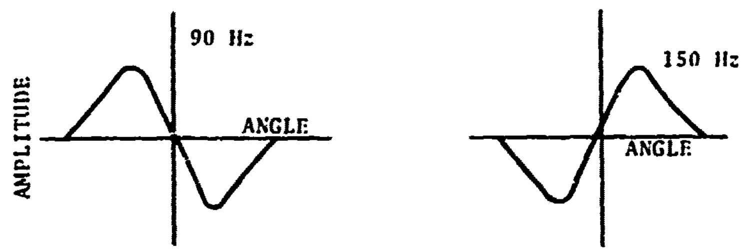


Figure 1b Relative Amplitudes and Phases In SO Pattern

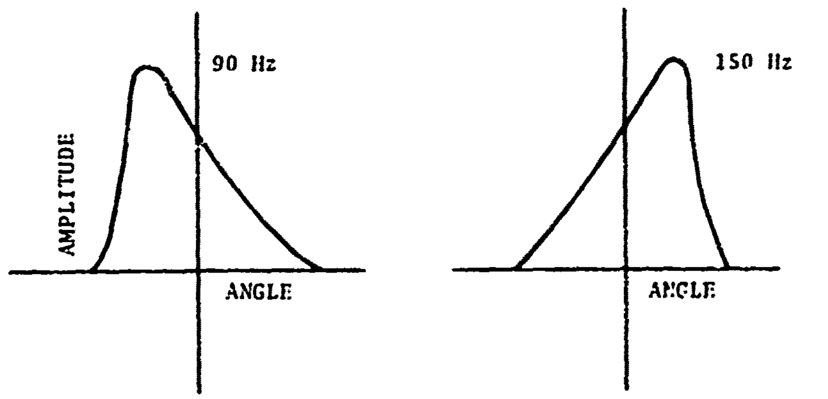


Figure 1c Resultant Modulation Patterns

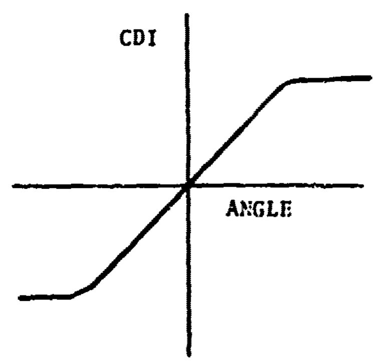


Figure 1d Course Deviation Indication (CDI)

Figure 1. Antenna Patterns Sketch

FAA standards for the ILS specify that within a certain narrow angular range about the course, the CDI should be closely proportional to the aircraft's angular deviation from course. This sector near the ideal approach is termed the "course sector" and usually extends between 1 1/2° and 3° to either side of the runway centerline. The wider sectors on either side of the course sector are called the "clearance sectors". In these sectors, which extend a minimum of 35° from the course, the CDI is required to always exceed a certain minimum magnitude. The presence of structures in the clearance sectors which scatter spurious signals into the course sector is the primary cause of derogation of the localizer CDI. Such structures are illuminated by carrier and sideband signals. The ratios of 150 Hz modulation to 90 Hz modulation in these signals are determined by the angular position of the structure with respect to the runway. In general these ratios are different from those transmitted toward the aircraft, due to the difference in angular position. The signals transmitted toward the scatterer will be reflected toward the aircraft. Thus the aircraft will receive the summations of the direct and scattered signals. Since, in general, the scattered signals will have improper ratios their effect is to distort the CDI. To combat this problem several new antenna systems have been designed. Two basic systems are used: the single antenna, and the "capture effect system."

The single antenna system radiates two patterns from one antenna array. The signal generated in the course sector is stronger than that generated in the clearance sector. However, because of the derogation effects, the signals are often not accurate enough to meet category II or III requirements and the more accurate "capture effect system" is used. This system uses one antenna array to broadcast a very narrow, powerful beam in the course sector. The second antenna array broadcasts a broader pattern, at a slightly different carrier frequency, which covers the clearance area. This system diminishes the derogation effects because of the dual frequency. The term "capture effect" has been used to describe this two antenna array system because the airplane receiver is "captured" by the stronger transmission signal.

3. ILS SIMULATION DESCRIPTION

The ILS simulation program makes it possible for airport planners to determine what the effects of potential airport buildings on the ILS performance are going to be. Thus, for example, if a new terminal or hotel is planned, the information as to size and location of the building can be input to the program and the derogation effect of that building can be determined. Because the derogation effect of these scatterers is so important, the program can warn the planner ahead of time to change the orientation or location of the building, or it can assure him that the building would not jeopardize the airport's current FAA rating.

The output of this program is a magnetic tape of values of the CDI. Graphs are generated by a plotting routine (using the values derived from the ILSLOC program) to show the CDI in microamperes, along a flight path, for the scattering surfaces input. These generated graphs would serve the same purpose as the FAA strip charts which are generated for a certifying flight. The simulation graph differs from the actual recorded measurements due to limitations of the program which will be explained later in the text.

The ILSLOC program simulates: transmission from the various types of localizer antenna systems; the trajectory of an aircraft flight over which the CDI is to be determined; and the scattering from rectangular and cylindrical surfaces. The program permits various simulated flight paths.

The program is not an exact simulation of the certifying flight, due to certain simplifying assumptions which were made. These assumptions include:

a. A flat perfectly conducting ground plane

b. Perfectly conducting reflectors

c. Far field scattering - all scattering from a surface is assumed independent of all other surfaces, thus multiple reflections from walls and near field interactions are ignored.

d. A noise free environment

e. Relative field strengths - the absolute field strengths involved are not calculated. Thus while we can calculate the CDI's in microamperes we do not ascertain the absolute electric field intensities.

f. An idealized ILS receiver model.

In addition to these assumptions the approximations of the scatterer can lose accuracy when the dimensions approach less than a few wavelengths. Since the program determines the scattering from a surface independently from all other scatterers, the shadowing of one structure on another is not included. Thus if one building is between the antenna system and another building, it will shield the second one from some or all of the ILS signal. The amount of energy reaching the second building will depend upon diffraction effects which are, in general, too complicated to analyze. It may be noted, however, that diffraction effects themselves are included as part of the physical optics approximation used (Ref. 1). By using rule of thumb approximations the analyst can determine roughly how much power will reach the second building. If the level is small the building may be ignored completely. If on the other hand the power level is large then the structure should probably be included as though there was no shielding effect. This will give a conservative CDI estimate (i.e. larger derogation than actual), but this will serve for most purposes. If the situation is critical, that is near category limits, then other means of analysis must be used.

Ref. 1 "Instrument Landing Systems Scattering" Report No. FAA-RD-72-137 (1972)

4. TEST CASE FOR THE ILSLOC COMPUTER PROGRAM

To illustrate how the computer program is operated a very simple test case (with only 2 scatterers) has been created and run. For this simulated airport the program computed the course width as 4.01 degrees. Both antenna arrays were set at an elevation of 13 feet above the ground plane. The clearance antenna array was used as the origin for the coordinate system. An 80'x100'x60' hangar and 75'x110' cylinder were placed on opposite sides of the 9,350 ft. runway. In this case the threshold is 10,000 ft. from the course antenna. (See illustration - Figure 2). Based on the size and locations of these two buildings, the model predicted the CDI on the runway centerline and for a clearance run at 10,000 ft. range.

Using this model for input values, the following section presents a detailed follow through of the main program steps.

The Mode Card

The first input is the mode card. This card contains information on the type of localizer antenna used, the frequency of the ILS, the length of the runway, and the height of the antenna.

The card format is:

Col.	Symbol	Usage	
1-2	Mode	= 1 (V-RING) = 2 (8-LOOP) = 3 (WAVEGUIDE) = 4 (VACANT) = 5 (MEASURED PATTERN) = 6 (MEASURED CAPTURE EFFECT PATTERNS) = 7 (THEORETICAL PATTERN) = 8 (THEORETICAL CAPTURE EFFECT PATTERNS) =-1 (V-RING CLEARANCE) =-2 (8-LOOP CLEARANCE) =-3 (WAVEGUIDE CLEARANCE) =-4 (MEASURED CLEARANCE PATTERNS)	indicates antenna type
11-20	FRQ	Frequency of ILS in Mega Hz	

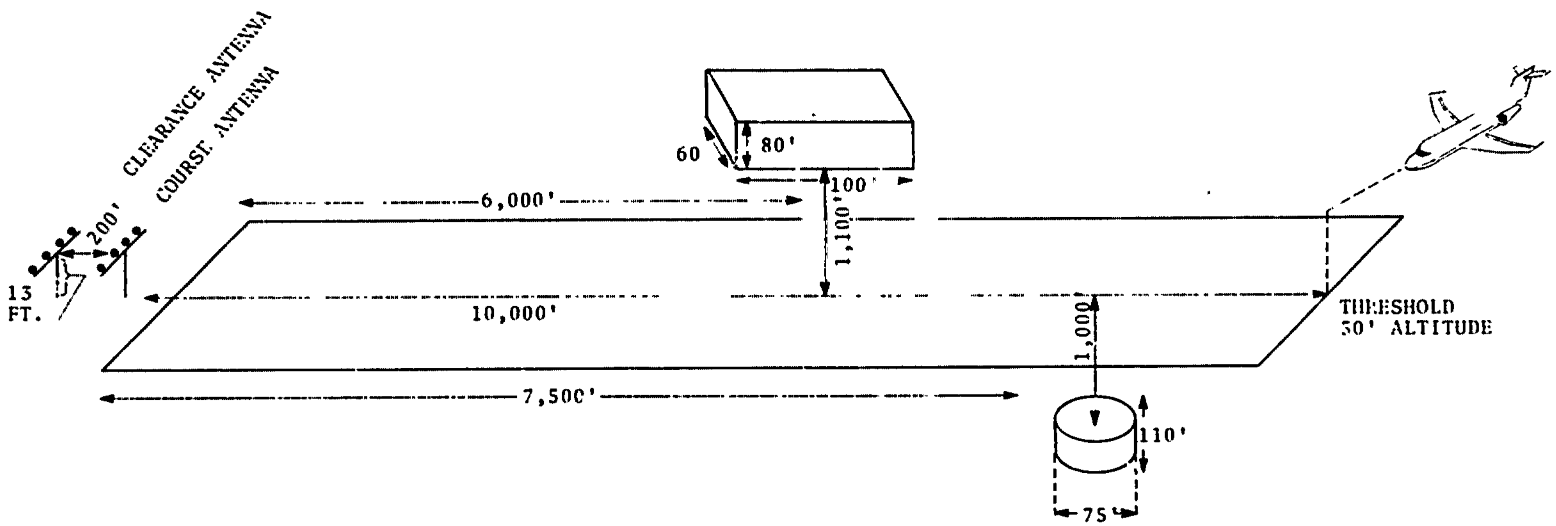


Figure 2. Simulation Airport

In order to effectively use the rest of the mode card columns it is important that the user understand the coordinate system used.

The x-axis is along the center line of the runway, the threshold being in the positive direction. The z-axis is vertical, positive z being in the up direction. The y-axis completes a right handed coordinate system: so that when one is standing at the origin facing in the x-direction positive y is to the left. The origin is used as a reference to define the location of scatterers, antenna system components, and flight path sample points. The antennae are located along the x-axis, they need not be at the origin; as in our test case, it is usually convenient to place the course antenna at the origin.

Col.	Symbol	Usage
21-30	XTH	Distance from the origin to the threshold of the runway, in feet. This number is used for both flight path orientation and for course width determination. The distance is given in feet.
31-40	ZA(1)	There is always a non-zero antenna height, and it is input here.
41-50	ZA(2)	This will be the clearance antenna height if a two antenna system is used.

Modes 1, 2, and 3 provide for standard localizer antenna array types. These antenna arrays are predetermined, the only variable being course width, the adjustment of which is controlled by the course width card.

When any array type other than mode 1, 2, or 3 is used, additional antenna array description cards must be included. Mode 5 permits the input of a measured pattern for special cases on theoretical studies. When this mode is selected additional pattern cards are required. One pattern card must be used for each measurement. The angles must be given in ascending order. A maximum of fifty measurements may be given; if less than fifty cards are used a termination card with an angle greater than 360 degrees must be inserted.

Format of Pattern Card(s)

Col.	Symbol	Usage
1-10	ANG	Angle of measurement, in degrees
11-20	AFPP	Amplitude of sideband only pattern, in relative units
21-30	AGPP	Amplitude of carrier plus sideband pattern, in relative units

Mode 7 allows the generation of a theoretical array pattern from assumed element contributions. The antenna is to be a linear array of elements with identical radiation patterns. Each element has an arbitrary magnitude and phase for both carrier plus sideband and sideband only currents. The arrays are assumed to be aligned parallel to the y-axis. All elements have the same height, as given in the mode card. All elements have the same x-coordinate as given on the course width card. The y-coordinate, in wavelengths, is given for each element on the element description card. There must be one card for each element in the array, to a maximum of 26 elements. The format for the element description card is:

Col.	Symbol	Usage
1-10	DT	Element displacement in the y-direction given in wavelengths
11-20	CT	Carrier plus sideband amplitude, in relative units
21-30	PC	Carrier plus sideband phase, in degrees
31-40	ST	Sideband only relative amplitude
41-50	PS	Sideband only phase, in degrees

The phase of the sideband only currents is ideally in quadrature to the carrier plus the sideband currents. This 90 degree shift is added by the program. Thus a "PS" inputted as zero degrees is internally converted to 90 degrees out of phase with the sideband portion of the carrier plus sideband. To indicate termination when there are less than 26 elements used, an element card is placed with a carrier plus sideband phase value (PC) of more than 500.

The next step for this mode must be the input of the horizontal radiation pattern for the individual element. This pattern will be used for each of the elements previously described. The input is the relative signal strength measured every 10° starting at 0 and proceeding until 180°. This is a total of nineteen amplitudes; the values are read in, in records of 8F10.4 format, for a total of 3 records. This gives the pattern for angles from, 0° to 180° and since the pattern is assumed to be symmetric the value for the negative angle will be the same s a positive one of equal magnitude.

There are two methods of inputting capture effect system descriptions. The most general way is to input each antenna array separately. When using this method the clearance array must be input first. This input will follow the same steps as a single array system except that the mode number will be a negative. The negative mode card and the pattern or element cards (if any) must be followed by another mode card. This mode for the course array must be positive, and followed by the necessary pattern or element cards.

There are two cases for the second method of inputting antenna array descriptions. The first case is used if both course and clearance antenna array are to be given as measured patterns; a single mode 6 card is used followed by two sets of pattern cards: the first set is for the course antenna array: and the second set for the clearance antenna array. The mode 6 is converted internally to a mode 5 for each array and these values will appear in the output listing. In the second case, for a capture effect system which uses two theoretical arrays, a mode 8 is used. This card is followed by the course antenna element description cards and the element radiation cards; a second set of array description cards is used in the clearance antenna. As in the mode 6 case, the mode 8 is converted internally to two mode 7's. These mode 7's will appear in the output listing.

In our test case:

Mode Card:

Col.	1-2	6
	11-20	110.
	21-30	100000.
	31-40	13.
	41-50	13.

Pattern Cards: see attached Figure 3 for test case listing.

The antenna description cards are followed by the course width card. The format for this card is:

Col.	Symbol	Usage
1-10	XXA(1)	Course array x-coordinate, in feet
11-20	XXA(2)	Clearance array x-coordinate, in feet
31-40	CW	Course width in degrees
41-50	CLS	Clearance signal strength relative to the course signal

If CW is greater than 3° this value is used as the course width and the signal strengths of the course antenna are automatically adjusted to produce this value.

If CW is less than 3° the course width will be set to the FAA specification for a threshold to antenna distance, given by XTH, and the signal levels will be set accordingly.

CLS is the ratio of clearance signal strength to course signal strength.

The test case course width card would read:

1-10	0.
11-20	-200.
31-40	0.0
41-50	.315

6	110.	10000.	13.0

-45.	-.012	0.00[illegible]
-42.	-.020	0.014
-40.	-.014	0.02[illegible]
-38.	0.000	0.020
-35.	0.018	0.0[illegible]
-32.	0.008	-.025
-30.	-.010	-.020
-28.	-.011	0.00[illegible]
-27.	-.008	0.01[illegible]
-26.	0.000	0.017
-25.	0.011	0.01[illegible]
-23.	0.020	0.00[illegible]
-20.	0.000	-.03[illegible]
-19.	-.010	-.041
-18.	-.015	-.035
-16.	0.000	0.00[illegible]
-14.	0.016	0.024
-13.	0.015	0.035
-12.	0.000	0.050
-9.	-.180	0.140
-5.	-.535	0.535
-4.	-.535	0.660
-1.	-.165	0.996
0.	0.000	1.000
1.	0.165	0.996
4.	0.535	0.66[illegible]
5.	0.535	0.535
9.	0.180	0.140
12.	0.000	0.050
13.	-.015	0.035
14.	-.016	0.024
16.	0.000	0.00[illegible]
18.	0.015	-.035
19.	0.010	-.041
20.	0.000	-.039
23.	-.020	0.00[illegible]
25.	-.011	0.019
26.	0.000	0.017
27.	0.008	0.01[illegible]
28.	0.011	0.0[illegible]
30.	0.010	-.02[illegible]
32.	-.008	-.02[illegible]
35.	-.018	0.00[illegible]
38.	0.000	0.02[illegible]
40.	0.014	0.0[illegible]
42.	0.020	0.[illegible]
45.	0.012	0.[illegible]
1000.		

Figure 3. Pattern Card Test Case Listing

-60.	0.000	0.000
-55.	-.085	0.018
-54.	-.096	0.019
-51.	-.145	0.008
-50.	-.160	0.002
-49.	-.175	0.005
-45.	-.245	0.050
-33.	-.411	0.400
-32.	-.414	0.430
-30.	-.426	0.475
-27.	-.464	0.497
-26.	-.475	0.499
-25.	-.490	0.497
-22.	-.545	0.486
-21.	-.565	0.485
-20.	-.585	0.486
-19.	-.602	0.490
-15.	-.676	0.540
-14.	-.680	0.560
-13.	-.680	0.585
-12.	-.675	0.620
-9.	-.610	0.730
-2.	-.160	0.980
0.	0.000	1.000
2.	0.160	0.980
9.	0.610	0.730
12.	0.675	0.620
13.	0.680	0.585
14.	0.680	0.560
15.	0.676	0.540
19.	0.602	0.490
20.	0.585	0.486
21.	0.565	0.485
22.	0.545	0.486
25.	0.490	0.497
26.	0.475	0.499
27.	0.464	0.497
30.	0.426	0.475
32.	0.414	0.430
33.	0.411	0.400
45.	0.245	0.050
49.	0.175	0.005
50.	0.160	0.002
51.	0.145	0.008
54.	0.096	0.019
55.	0.085	0.018
60.	0.000	0.000
1000.		

Figure 3. Pattern Card Test Case Listing (Cont.)

The label card follows the course width card. This card is put on the output tape ahead of the CDI records for this flight. It serves as an identifying record and is the label placed on the graph. Columns 1-80 are used. In our test case this card reads: THIS IS A DEMONSTRATION CASE OF STRAIGHT LINE FLIGHT.

The program calculates the CDI at a point in space: for convenience, the program will permit calculation for a series of points. This set of points represents samples of a simulated flight path.

The program allows two types of flight paths. A straight line flight and a circular orbit. The flight path card has one of the following formats:

Straight Line Flight

Col.	Symbol	Usage
1-10	XMIN	Starting distance from origin, in feet
11-20	XMAX	Ending distance from origin, in feet
21-30	DXR	Spacing between sample points, in feet
31-40	PHIR	Angle of approach, in degrees
41-50	PSIR	Glide angle, in degrees
61-70	ZUP	Height of aircraft at threshold, in feet

XMIN is the x-coordinate of the starting location of the aircraft and XMAX is the x-coordinate of the ending location. The sample points are spaced along a straight line so that the difference in x-coordinates between successive samples is DXR. The sign of the DXR will be set by the program so that the flight goes from XMIN to XMAX regardless of flight direction. If the DXR value would require more than 500 points the program will adjust the magnitude of DXR to give only 500 points. In some cases a flight will require more than 500 points. If this is necessary the flight must be broken up into smaller segments

of not more than 500 points each. The procedure for doing this is explained in the control card section. The flight path is oriented in space so that an extension of the path crosses the threshold at the altitude of ZUP and intersects the z-axis. PHIR is the angle between the flight path and the vertical plane through the runway centerline. It is zero for a flight path along the centerline of the runway and is positive for an incoming flight (XMIN greater than XMAX) with decreasing y-displacement. PSIR is the glide angle between the flight path and the horizontal plane. It is zero for level flight and positive for a normal landing approach. The flight path is a straight line as described above except when the x-component is less than XTH, that is if the aircraft is on the antenna side of the threshold. In that case the aircraft altitude will be set up to ZUP.

Thus the values used in the test case would read:

Col.	1-10	40000.
	11-20	20000.
	21-30	-40.
	31-40	0.
	41-50	2.5
	51-60	50.

The arc flight is a series of points at a constant height of ZUP and at a constant horizontal distance from origin of R. MIND is the starting angle for the arc, that is, the line of sight from the origin to the point makes a horizontal angle of MIND degree with the x-axis. The sample points are spaced at equal angles of DXR until the termination angle of MIND is reached. As in the straight line flight the sign of DXR will be adjusted appropriately. Likewise the magnitude of DXR will be set to yield not more than 500 points. Column 74 must be set to 1 to indicate a circular arc.

Circular Orbit Case

Col.	Symbol	Usage
1-10	MIND	Starting angle, in degrees
11-20	MAXD	Ending angle, in degrees

Col.	Symbol	Usage
21-30	DXR	Angular spacing between samples, in degrees
51-60	R	Radius of orbit, in feet
61-70	ZUP	Height of orbit, in feet
74	ICF	Must be set to 1 to indicate orbit case

Following the flight path card must be the velocity card in the following format:

Col.	Symbol	Usage
1-10	VEL	Velocity of aircraft, in feet/sec. This is used for the Doppler Effect on the receiver. The sign of the velocity will be made to agree with the directional motion from DXR. Test case assumes velocity of 200 ft./sec.

At this point we have described the antenna system and the trajectory of the aircraft; the derogating surfaces in proximity to the ILS must now be described. The program will simulate scattering from rectangular or cylindrical surfaces. We will now describe the method of inputting scatterers to simulate derogating structures.

The next card describes either the scatterer(s) or output and control. The usage is determined by the value of the ID field in columns 1 to 2. An ID of -1, 1 or 2 is used for scatterers, while the other values are used for control.

An ID of 1 is used for a rectangular scatterer and has the following format:

Col.	Symbol	Usage
1-2	ID	Must be 1 for rectangle
3-8	XW(1)	X-coordinate of reference point, in feet
9-14	XW(2)	Y-coordinate

Col.	Symbol	Usage
15-20	XW(3)	Z-coordinate
26-30	ALPHA	Angle between base and x-axis, in degrees
31-35	DELTA	Angle of tilt, in degrees
36-45	WW	Width of rectangle, in feet
46-55	HW	Height along rectangle, in feet

The scatterer is a rectangle with the reference point at the middle of the base. The rectangle is assumed to be of infinite conductivity and zero thickness. It also has only one side. This can be thought of as the front surface of a metal wall. A wall with zero x-, y-, and z coordinates and an alpha of zero is located at the origin with surface of the wall facing in the negative y direction (Figure 4, case I). A positive increase in alpha rotates the wall about the z-axis in a counterclockwise direction when viewed from above. Thus an alpha of ninety degrees faces the wall in the positive x direction (Figure 4, case II). Alpha is the angle between the vertical projection of the base of the wall in the xy-plane and the x-axis, measured in degrees. Delta is the angle between the surface of the wall and the vertical direction, in degrees. A delta of zero is a wall perpendicular to the ground and a decrease in delta rotates the wall about the baseline in a direction so that a delta of minus ninety is a horizontal wall facing down (Figure 4, case III). WW is the width, in feet, of the wall measured along its base and HW is the height measured along the surface at right angles to the base. If the wall is oriented in such a fashion that the line of sight from the antenna to the wall passes through the back and not the front of the wall, the program will ignore the wall in the simulation.

An ID of -1 is used with the above format to describe a negative wall. This ID is used, for example, to create a wall with a rectangular hole in it. The entire surface is used; the hole is then subtracted by inputting a second card with an ID of -1 and the size, location, and orientation of the hole.

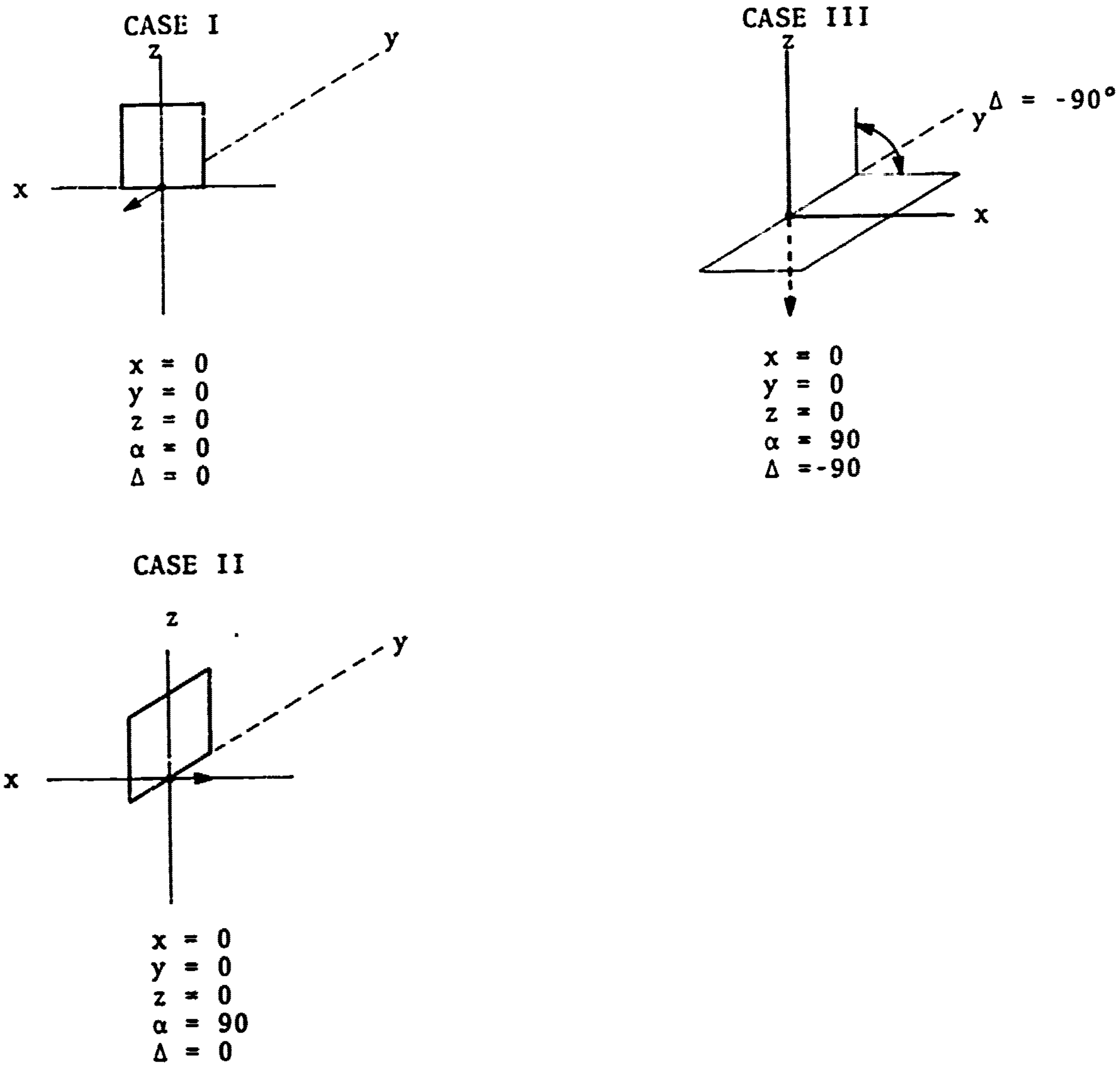


Figure 4. Illustration of Orientation Nomenclature for Rectangular Surface

An ID of 2 is used for a cylindrical scatterer with the following format:

Col.	Symbol	Usage	
1-2	ID	Must be a 2	
3-8	XW(1)	x-	coordinates of the reference point, in feet
9-14	XW(2)	y-	
15-20	XW(3)	z-	
36-45	WW	Diameter of cylinder, in feet	
46-55	HW	Height of cylinder, in feet	

The reference point is located at the base of the cylinder on the axis of rotation of the cylinder. The diameter is WW feet, with the base parallel to the xy plane at an altitude of XW(3) feet. The cylinder extends upward for HW feet with the axis of rotation in the vertical direction. The cylinder is assumed to have infinite conductivity.

After an ID of -1, 1 or 2, the program will calculate the electric field at the surface of the scatterer. This will be calculated from the signal from the transmission antenna array and from the ground reflection of the transmitted signal. Then, for each receiver point along the flight path, the program will calculate the electric field at that location from the scattered signal: from both the scatterer and reflected from the ground. Thus, the signal is received from four paths: transmission antenna to scatterer to receiver; antenna to ground to scatterer to receiver; antenna to scatterer to ground to receiver; and antenna to ground to scatterer to ground to receiver. This signal is decomposed into complex components induced in the receiving antenna at the different carrier and sideband frequencies. The program then loops back to read in another ID card, permitting the summation of the effects of many scatterers. This allows the simulation of complex structures by breaking them up into cylinders and rectangles.

In the test case, we have only inputted three scattering surfaces. This was done because only two sides of the hangar and the cylinder are illuminated. The values for the scatterer cards read:

Col.	First card	Second card	Third card
1-2	1	1	2
3-8	6000.	5950.	7500.
9-14	1100.	1130.	-1000.
15-20	0.	0.	0.
26-30	10.	-80.	0
31-35			
36-45	100.	60.	75.
46-55	80.	80.	110.

After all the scatterers have been input, a control card is inserted to terminate the run. The control card format is:

Col.	Symbol	Usage
1-2	ID	not -1, 1, or 2

When a control card is read in, the program will add the direct, and ground reflected signal from the transmission antenna to the scattered signal summations, thus giving the total received signal. The program then calculates the CDI that would be seen at each receiver point, and outputs the label, a header record describing the flight path and the values of the CDI on output tape. If the ID is equal to zero the program also outputs additional records for the strengths of sideband and carrier signals from course and clearance (if any) antenna arrays. The field summations are then cleared for the next run.

The program, having finished the previous run, now proceeds with the next input. The next run is generated by looping back to a point in the input stream, determined by the value on the control card.

Once an input sequence has begun the inputs following in the standard order must be given. The user must also keep in mind that all values on cards given before that entry point, in the previous run are still in effect. The standard order is:

MODE CARD
(measured pattern for modes 5 and 6 or current description for modes 7 and 8)
(second mode card and patterns of currents if first mode was negative)
COURSE WIDTH CARD
LABEL CARD
FLIGHT PATH CARD
VELOCITY CARD
(set of scatterer cards)
CONTROL CARD

The value of the ID on the control card guides the looping in the following manner:

Value of ID	Next card to be read in
0	MODE
3-10	SCATTERER
11-15	LABEL
16-20	MODE
21-50	COURSE WIDTH
>50	WILL CAUSE THE PROGRAM TO TERMINATE AFTER OUTPUTTING THE LAST CDI

The looping permits the repetition of a run with changes in some or all of the variables. For example, ID values 3 through 10 permit a run with the same antenna system and flight path as the previous case, but with a new set of scatterer inputs.

ID values 11 - 15 permit a new flight path description and scatterer set to be input. This looping method can also be used for flights that would require more than 500 points. For reliable simulation, the spacing between receiver points (DXR) should be small enough so that the change in CDI between successive points is not more than ~20% of the peak value. Thus for long flights the flight path must be broken up into shorter segments. If the number

of segments of this path does not exceed 4, the plotting program will connect them on a single graph. The control for this joining is the ID number. If the flight path finishes with an ID of 11 - 13, the graph of the next flight will continue the line of the graph. A long flight may be broken up into as many as four segments: with three segments terminating in 11 - 13 and a fourth, and final segment, terminating in 14 or 15. The flight segments must appear in the order in which they are to be flown, so that the XMIN of one section is the XMAX of the previous section. For each segment the programmer must re-input the same scatterers. If only one segment is to be plotted the control card should read 14 or 15.

ID's 16 through 20 start inputting at the mode card, thus allowing a completely new run.

An ID of 21 through 50 uses the same antenna description, but starts the inputting at the course width card. This permits the course width, clearance strength and antenna location to be varied.

The program is terminated after an ID greater than 50 is encountered. The direct signal will be added, and the CDI will be outputted before the program stops. The program will also stop if an end-of-file is encountered while the program is attempting to read any input card, or if certain of the variables are of improper value. In these cases the program terminates immediately, without outputting the last case.

The input of the test case flight path was done in four segments. The first segment is from 40,000' to 20,000', the second segment is from 20,000' to 12,500', the third segment is from 12,500' to 11,000' and the last is from 11,000' to 10,000'. An additional case for a simulated clearance flight by a circular orbit has also been included. The input cards for these test case flights are shown in Figure 5.

```
  THIS IS A DEMONSTRATION CASE OF STRAIGHT LINE FLIGHT
 40000.     20000.        -40.                      2.5                 50.
200.
 16000. 1100.             10.        100.       80.
 15950. 1130.            -80.         60.       80.
 27500. -1000.  0.          0.     0.  75.       110.
13
  THIS IS A DEMONSTRATION CASE OF STRAIGHT LINE FLIGHT
 20000.     12500.        -15.                      2.5                 50.
200.
 16000. 1100.             10.        100.       80.
 15950. 1130.            -80.         60.       80.
 27500. -1000.  0.          0.     0.  75.       110.
13
  THIS IS A DEMONSTRATION CASE OF STRAIGHT LINE FLIGHT
 12500.     11000.        -3.                       2.5                 50.
200.
 16000. 1100.             10.        100.       80.
```

```
 15950. 1130.            -80.         60.       80.
 27500. -1000.  0.          0.     0.  75.       110.
13
  THIS IS A DEMONSTRATION CASE OF STRAIGHT LINE FLIGHT
 11000.     10000.        -2.                       2.5                 50.
200.
 16000. 1100.             10.        100.       80.
 15950. 1130.            -80.         60.       80.
 27500. -1000.  0.          0.     0.  75.       110.
15

      THIS IS ORBIT CASE WITH SIGNAL STENGTHS
  180.      180.       0.72                              10000.     50.
 200.
  16000. 1100.             10.        100.       80.
  15950. 1130.            -80.         60.       80.
  27500. -1000.  0.          0.     0.  75.       110.
```

Figure 5. Flight Case Inputs

APPENDIX A

MAIN PROGRAM LISTING

INCLUDING COMMENTS EXPLAINING

THE PROGRAM

```
C     ILS SINGLE REFLECTION INTERFERENCE PROGRAM  ILSLOC
C THIS PROGRAM SIMULATES THE EFFECTS OF RECTANGULAR
C AND CYLINDRICAL SCATTERERS ON THE LOCALIZER PART
C OF THE ILS.  THESE COMMENTS SERVE AS THE PROGRAM DESCRIPTION
C FOR THE USER.  A USER,S MANUAL HAS BEEN WRITTEN AND
C THIS COMMENTARY IS WRITTEN ASSUMING THE USER HAS READ IT.
C
C
C
C ILBL IS USED TO IDENTIFY THE SIGNAL STRENGH OUTPUTS  AS
C TO TYPE AND SOURCE.  THE FIRST CHARACTER IS  ,S, FOR
C SIDEBAND ONLY SIGNALS OR  ,C, FOR CARRIER PLUS SIDEBAND.
C THE SECOND PAIR ARE ,CR, FOR COURSE ANTENNA OR ,CL, FOR
C CLEARANCE.
C
      DIMENSION ILBL(5)
      DATA ILBL/4HC CR,4HS CR,4HC CL,4HS CL,4H CDI/
C
C
C
      LOGICAL EOF
      DIMENSION MEMO(14),DF(501)
      COMPLEX BESF,FAC,CE
      COMPLEX EP,EE,EM,EC,ZE(4),ZD(1),EWR,FPP,GPP,FPM,GPM,
     2        CS(25,2),SO(25,2)
      COMPLEX ZJM,ZJP,ZJPC(2),ZJMC(2)
      COMPLEX  ZP(500),ZPC(500,2),ZM(500),ZMC(500,2)
      DIMENSION XXRY(500,4)
      DIMENSION VCD(500,2),VPD(500,2),VMD(500,2)
      DIMENSION  XW(3),XW0(3)
      DIMENSION AN(3)
      DIMENSION AFOO(9),PHS(9)
      DIMENSION XY(10)
      REAL LAMBDA
      COMMON/CD/ ARAD(50),AFPP(50),AGPP(50),BRAD(50),BFPP(50),BGPP(50)
      COMMON /AB/ ZJM,ZJP,ZJPC,ZJMC
      COMMON     ZP,ZPC,ZM,ZMC,VCD,VPD,VMD
      COMMON /VAR/ SM,SNCUT,SNCUD,SNCUC(2),VPC(2),VMC(2)
      COMMON /SUB/ MODE,ICP,FRQ,LAMBDA,PI,RADD,PHI(3),PSI(3),NEL,XTH,
     1 XXA(3),YA,ZA(3),RA(3)
      COMMON /ANT/ LOC,FPP,FPM,GPP,GPM,EWR(4,4),CWA(2),AS,CLS,DE(25,2),
     .           CS,SO,ET(20,2),ND(2)
      EQUIVALENCE (ZP(1),ZD(1)),(XXRY(1,1),ZP(1))
      DATA RAD/57.2957795/
C
C CP AND CM ARE THE AMOUNTS OF MODULATION ON THE CARRIER
C FOR THE CARRIER PLUS SIDEBAND.  CP IS THE COURSE MODULATION
C AND CM THE CLEARANCE.
C
      DATA CP,CM/.2,.2/
C
C
C
C THE OUPUT OF THE SIMULATION IS ON UNIT 8.  A TAPE WITH
C WRITE RING SHOULD BE PLACED THEREON.
```

```
C
      REWIND 8
C
C
C NC IS THE COUNT OF THE CASE BEING SIMULATED IT,S VALUE IS WRITTEN
C ON THE TAPE WITH THE OUTPUT RECORD.  THIS WOULD ALLOW
C SEARCHING FOR A PARTICULAR CASE BY NUMBER.
C
      NC=0
C
C
C THIS IS THE STARTING POINT FOR A SIMULATION.  IT IS ALSO
C ENTERED FOR A RESTART FOLLOWING AN ID OF 0 OR 16 TO 20.
C
    1 CONTINUE
      MODE = 122
C
C NEL IS THE NUMBER OF ANTENNAE IN THE SYSTEM.  DEFAULT
C CONDITION IS ONE ANTENNA
C
      NEL = 1
C
C
C EWR IS A COMPLEX MATRIX CONTAINING THE SIDEBAND ELECTRIC FIELD
C DESCRIPTION PRODUCED BY THE ANTENNA SUBROUTINE.  EWR(I,J)
C IS THE FIELD FOR THE ,I,TH ANTENNA.  AND THE ,J, VALUES
C HAVE THE FOLLOWING SIGNIFIGANCE:
C       J          USAGE
C       1        SIDEBAND PORTION OF CARRIER PLUS SIDEBAND
C                 FOR THE COURSE SECTION OF THIS ANTENNA
C       2        SIDEBAND ONLY FOR THE COURSE
C       3        SIDEBAND PORTION OF CARRIER PLUS SIDEBAND
C                 FOR THE CLEARANCE SECTION
C       4        SIDEBAND ONLY FOR THE CLEARANCE
C
C  THIS SUBROUTINE CALL IS USED TO CLEAR EWR BEFORE
C STARTING THE SIMULATION
C
      CALL CLEAR(EWR,16)
C
C
C THIS IS A TEST FOR END-OF-FILE ON CARD INPUT.  THE CALL TO
C EOF ARMS THE INTERUPT.  AT END OF FILE ON UNIT 5 INTERUPT IS
C TO STATEMENT 58.
C
    2 CONTINUE
      IF(EOF(5)) GO TO 58
C
C
C THIS IS THE INPUT FOR THE MODE CARD. THE VARIABLES HAVE
C THE FOLLOWING USES:
C
C       SYMBOL  USE
C       MODE    ANTENNA TYPE
C       =1      V-RING COURSE
C       =2      8-LOOP COURSE
```

```
C         =3      WAVEGUIDE COURSE
C         =4      NOT USED
C         =5      MEASURED COURSE PATTERN
C         =6      MEASURED COURSE AND CLEARANCE PATTERNS
C         =7      THEORETCAL COURSE ARRAY
C         =9      THEORETICAL COURSE AND CLEARANCE ARRAY
C         =-1     V-RING CLEARANCE
C         =-2     8-LOOP CLEARANCE
C         =-3     WAVEGUIDE CLEARANCE
C         =-5     MEASURED CLEARANCE PATTERN
C         =-7     THEORETICAL CLEARANCE ARRAY
C
C         FRQ     FREQUENCY OF TRANSMISSION
C         XTH     DISTANCE TO THRESHOLD
C         ZA(I)   ,I,TH ANTENNA HEIGHT
C
C ORIGIN IS AT THE CENTER OF COORDINATE SYSTEM.
C X-AXIS IS ALONG RUNWAY
C Z-AXIS IS STRAIGHT UP
C Y-AXIS COMPLETES A RIGHT HANDED SYSTEM
C
      READ (5,1001) MODE,FRQ,XTH,ZA
C
C
C THIS IS A TEST FOR INVALID ANTENNA TYPE.  THE PROGRAM ABORTS IN CASE
C OF ERROR.  THIS IS USUALLY CAUSED BY OMISSION OF OTHER CARDS
C WHICH CAUSE SOMETHING OTHER THAN A MODE CARD TO BE READ AT
C THIS POINT.
C
      IF( MODE .GT. 8 ) GO TO 58
      IF( MODE .LT. -7) GO TO 58
      IF( MODE .EQ. 0) GO TO 58
C
C
C THIS IS TEST FOR NEGATIVE MODE  INDICATING CLEARANCE ANTENNA.
C IF MODE IS POSITIVE FLOW IS TO STATEMENT 4
C
      IF( MODE .GT. 0 ) GO TO 4
C
C ICP IS THE ANTENNA TYPE FOR THE CLEARANCE ANTENNA
C
      ICP = - MODE
C
C
C IF THERE IS A CLEARANCE ANTENNA THEN THE NUMBER OF ANTENNAE
C IS SET TO 2.
C
      NEL = 2
C
C
C IF THE CLEARENCE ANTENNA IS SPECIFIED BY A MEASURED PATTERN IT IS
C NOW READ IN BY SUBROUTINE PATTRN.
C
      IF( ICP .EQ. 5 ) CALL PATTRN(BRAD,BFPP,BGPP)
C
C
```

```
C IF THE CLEARENCE ANTENNA IS SPECIFIED BY ARRAY PARAMETERS THE INPUT
C DATA FOR  THE ARRAY IS NOW READ IN BY  CRRNTS.
C
      IF(ICP .EQ. 7) CALL CRRNTS (DE(1,2),CS(1,2),SO(1,2),ET(1,2),ND(2))
C
C
C THE FLOW IS NOW BACK TO STATEMENT 2 TO READ IN
C MODE CARD FOR COURSE ANTENNA.
C
      GO TO 2
C
C
C THIS IS THE INPUT SECTION FOR THE COURSE ANTENNA IF PATTERNS OR
C ARRAY DESCRIPTION MUST BE GIVEN, OTHERWISE FLOW IS TO THE
C INITIALIZATION SECTION.
C
    4 IF( MODE .LT. 5 ) GO TO 6
C
C
C THIS STATEMENT CONTROLS THE INPUT METHOD, PATTERN OR ARRAY,
C ACCORDING TO MODE TYPE.
C
      IF (MODE .GT. 6) GO TO 5
      CALL PATTRN(ARAD,AFPP,AGPP)
C
C
C THIS IS TO INPUT THE SECOND PATTERN FOR CLEARANCE ANTENNA IF
C MODE IS 6.
C
      IF( MODE .EQ. 5) GO TO 6
      CALL PATTRN(BRAD,BFPP,BGPP)
C
C THE NUMBER OF ANTENNAE AND THE ICP TYPE ARE SET, THEN FLOW IS TO
C INITILAIZATION.
C
      NEL = 2
      MODE=5
      ICP = 5
      GO TO 6
C
C
C THIS IS THE INPUT FOR COURSE ARRAY DATA.
C
    5 CALL CRRNTS (DE,CS,SO,ET,ND(1))
C
C
C THIS TEST IS FOR CLEARANCE ARRAY IF MODE
C IS TYPE 8
C
      IF ( MODE .EQ. 7) GO TO 6
      CALL CRRNTS (DE(1,2),CS(1,2),SO(1,2),ET(1,2),ND(2))
      MODE=7
      ICP=7
      NEL=2
C
C
```

```
C THIS IS THE INITIALIZATION SECTION.  LAMBDA IS THE WAVELENGTH
C IN FEET AND AK IS THE PHASE SHIFT/DISTANCE IN RADIANS/FOOT.
C YA IS THE Y-COORDINATE OF THE ANTENNAE.  THIS IS ASSUMED TO
C BE ZERO I. ALL CASES.
C
    6 LAMBDA=11980./FRQ/12.
      AK=2.*PI/LAMBDA
      YA=0.0
      ZZ = 0.
      IF(EOF(5)) GO TO 58
C
C
C THIS IS THE COURSE WIDTH INPUT.
C XXA(1) IS THE X-COORDINATE OF THE COURSE ANTENNA
C XXA(2) IS THE X-COORDINATE OF THE CLEARANCE ANTENNA
C CW IS THE COURSE WIDTH
C CLS IS THE RATIO OF CLEARANCE TO COURSE SIGNAL STRENGTH.
C
      READ (5,1000) XXA,CW,CLS
C
C
C SET THE DEFAULT CONDITION ON CLS OF 1.
C
      IF( CLS .LE. 0.0 )  CLS = 1.0
C
C
C CWA(I) IS THE COURSE WIDTH ADJUSTMENT ON THE ,I,TH ANTENNA
C IT SETS THE SIDEBAND TO CARRIER RATIO. THE CLEARANCE ANTENNA
C (CWA(2)) IS ALWAYS 1.0 .  THE COURSE WIDTH IS ADJUSTED
C BY VARING THE COURSE ANTENNA (CWA(1)).
C
      CWA(1) = 1.0
      CWA(2)=1.0
C
C
C THE PROGRAM WILL NOW CALCULATE THE CDI FOR 2.5 DEGREE COURSE
C OFFSET.  THIS IS USED TO NORMALIZE THE SIDEBAND LEVEL TO
C ACHIEVE THE DESIRED COURSE WIDTH.  LOC IS THE TYPE OF ANTENNA
C USED BY THE ANTENNA SUBROUTINE, PSI(1) IS THE ANGULAR ALTITUDE
C OF THE REFERENCE POINT AND PHI(1) IS THE AZIMUTH OF THE POINT.
C
      PSI(1) = 5.E-03
      PHI(1) = 2.5*RAD3
      LOC = MODE
C
C
C THE MODE IS USED TO DETERMINE WHICH ANTENNA SUBROUTINE TO CALL.
C CSP IS THE STANDARD ANTENNA ROUTINE, IT COVERS THE V-RING
C 8-LOOP AND WAVEGUIDE.  LNAR IS THE ARRAY ANTENNA SUBROUTINE.
C ANTP IS THE MEASURED PATTERN SUBROUTINE. THE SUBROUTINE WILL
C RETURN FPP AND GPP FOR THE POINT AT PHI,PSI AND UNIT RANGE.
C FPP IS THE SIDEBAND ONLY LEVEL.  GPP IS THE SIDEBAND LEVEL
C FOR THE CARRIER PLUS SIDEBAND.  AFTER THE RETURN, FLOW IS TO
C STATEMENT 9.
C
      IF (MODE .GE. 7) GO TO 8
```

```
      IF(MODE .GE. 5) GO TO 7
      CALL CSP
      GO TO 9
    7 CALL ANTP (FPP,GPP,ARAD,AFPP,AGPP)
      GO TO 9
    8 CALL LMAR ( FPP,GPP,PHI,DE,CS,SO,ET,ND)
      GO TO 9
C
C
C THE SIGNAL LEVELS ARE IN FPP AND GPP.  TEMP IS THE APPARENT
C COURSE WIDTH WITH CWA,S OF 1.0.
C
    9 TEMP= 1.9375/REAL(FPP/GPP)
C
C
C THE COURSE WIDTH READ IN IS USED IF IT IS LARGER THAN 3 DEGREES
C OTHERWISE THE STANDARD VALUE BY FAA SPECIFICATIONS IS
C DETERMINED AND THIS VALUE USED.  THE COURSE WIDTH IS LIMITED
C TO A RANGE OF 3 TO 6 DEGREES.
C
      IF( CW - 3.0 ) 10,10,11
   10 CW = 2.*ATAN(350./XTH ) * RAD
      IF( CW .LT. 3.0 ) CW = 3.0
      IF(CW .GT. 6.0) CW=6.0
C
C
C THE CWA(1) IS ADJUSTED TO PRODUCE THE DESIRED COURSE WIDTH.
C
   11 CWA(1) = TEMP/CW
C
C
C THE VALUES, READ IN AND CALCULATED, FOR THE ANTENNA SYSTEM(S)
C ARE OUTPUT ON THE LINE PRINTER (ASSUMED TO BE UNIT 6)
C
      WRITE(6,1003) MODE,ICP,FRQ,XTH,ZA,XXA,CW
      WRITE(6,1000) TEMP,CWA
      WRITE(6,1002) CLS
C
C
C THIS IS THE LOOP BACK POINT FOR NEW FLIGHT PATH, ID,S 11 TO 15.
C MEMO IS THE LABEL.FOR HEADER RECORDS AND GRAPHS.
C INPUT DATA FOR FLIGHT PATH:
C         XMIN    STARTING POINT
C         XMAX    ENDING POINT
C         DXR     SAMPLE POINT SPACING
C         PHIR    ANGLE OF APPROACH
C         PSIR    GLIDE ANGLE
C         R       RADIUS OF ORBIT
C         ZUP     ALTITUDE AT THRESHOLD OR OF ORBIT
C         ICF     FLAG 0 FOR STRAIGHT LINE, 1 FOR ORBIT
C
   14 CONTINUE
      READ (5,1005) MEMO
      WRITE(6,1004) MEMO
      READ (5,1006) XMIN.XMAX,DXR,PHIR,PSIR,R,ZUP,ICF
C
```

```
C
C THE SIGN OF DXR IS ADJUSTED FOR FLIGHT FROM XMIN TO XMAX.
C
      DXR=SIGN(DXR,(XMAX-XMIN))
C
C
C THE VELOCITY OF THE AIRCRAFT IS INPUT.
C
      READ (5,1006) VEL
      WRITE (6,1007) VEL
C
C THE SIGN OF THE VELOCITY IS SET TO AGREE WITH THAT OF DXR.
C
      VEL=SIGN(VEL,DXR)
C
C
C THE NUMBER OF RECEIVER POINTS IS DETERMINED.  IF THIS IS
C LESS THAN 502 FLOW PROCEEDS TO STATEMENT 16. OTHERWISE THE
C MAGNITUDE OF DXR IS INCREASED TO GIVE ONLY 501 POINTS.
C
      NR =IFIX( (XMAX-XMIN)/DXR + 1.)
      IF(NR .LT. 1) GO TO 15
      IF(NR-501) 16,16,15
   15 WRITE (6,1008)
      DXR=(XMAX-XMIN)/500.
      IF(ABS(DXR) .LT. 1.E-5) GO TO 98
      NR = 501
   16 CONTINUE
C
C
C THE FLIGHT PATH DESCRIPTION IS OUTPUT.  THE FORMAT BEING DETERMINED
C BY THE TYPE OF FLIGHT.  IN THE CASE OF STRAIGHT LINE THE
C NECESSARY CONSTANTS FOR DOPPLER EFFECTS AND POSITION ARE
C DETERMINED.
C AFTER OUTPUT FLOW IS TO STATEMENT 19.
C
      IF (ICF) 18,18,17
   17 WRITE (6,1015) XMIN,XMAX,DXR,XTH,ZUP,ICF
      GO TO 19
   18 CONTINUE
      WRITE (6,1009) XMIN,XMAX,DXR,PHIR,PSIR,XTH,ZUP
      PHIR=PHIR/RAD
      PSIR=PSIR/RAD
      SPSI = SIN(PSIR)
      TANSR=SPSI/COS(PSIR)
      TANPR=SIN(PHIR)/COS(PHIR)
      VX=VEL*COS(PSIR)*COS(PHIR)
      VY=VEL*COS(PSIR)*SIN(PHIR)
      VZ=VEL*SIN(PSIR)
   19 CONTINUE
C
C
C THESE CONSTANTS ARE FILTER FACTORS FOR THE ASSUMED MODULATION
C FILTERS.
C
      TA=1./15.
```

```
      PTA = FI*TA
      W6PT = 6?.*PTA
      W9?T = 92.*PTA
      W1??T = 15?.*PTA
C
C
C THIS IS THE LOOP BACK POINT TO START A NEW SIMULATION WITH
C PREVIOUS ANTENNA SYSTEM AND FLIGHT PATH.  THE COMPLEX FIELD
C SUMMATION MATRICIES ARE CLEARED, THE CASE NUMBER IS
C INCREMENTED BY ONE AND THE LINEPRINTER HEADERS ARE WRITTEN.
C
   20 CONTINUE
      CALL CLEAR(ZP,4500)
      NC = NC + 1
      WRITE (6,1010)
      WRITE (6,1011)
C
C
C THIS IS THE INPUT FOR A NEW SCATTERER OR CONTROL CARD.  THE
C FORMAT AND USAGE OF THE VARIABLES WILL BE FOUND IN THE USER,S MANUAL.
C
   21 READ (5,1012) ID,XW(1),XW(2),XW(3),ALPHA,DELTA,WW,HW
C
C
C A NEGATIVE ID IS USED ON A SCATTERER TO CAUSE THE FIELDS TO
C BE SUBTRACTED FROM THE SUM.  THUS IDA IS USED TO DETERMINE
C THE TYPE OF SCATTERER AND THE SIGN OF ID IS USED FOR THE
C SIGN DTERMINATION OF THE FIELDS.
C
      IDA=IABS(ID)
C
C
C THE RECEIVER POINT LOCATION VARIABLES ARE INITIALIZED.  XR IS
C THE X-COORDINATE OF THE LOCATION, ZR IS THE Z-COORDINATE
C AND CDEG IS THE AZIMUTH.  THE USE OF THESE VARIABLES IS CONTROLLED
C BY THE VALUE OF ICF.
C
      IF (ICF) 23,23,22
   22 CDEG=XMIN-DXR
      ZR=ZUP
      GO TO 24
   23 XR=XMIN-DXR
   24 CONTINUE
C
C
C IF IDA IS NOT 1 OR 2 THEN THIS CARD IS A CONTROL CARD AND
C FLOW PASSES TO STATEMENT 43 TO OUTPUT THE CDI AND FOR
C LOOPING CONTROL.
C
      IF(IDA .GT. 2) GO TO 43
      IF(IDA .EQ. 0) GO TO 43
C
C
C XY IS AN ARRAY OF DATA ON THE ANTENNA AND FLIGHT PATH AND IS
C OUTPUT AS PART OF THE HEADER RECORD ON THE OUTPUT TAPE.
C
```

```
      XY(1) = P.IR
      XY(2) = PSIR
      XY(3) = ZUP
      XY(4) = FLOAT(NC)
      XY(5) = VEL
      XY(6) = FLOAT(MODE)
      XY(7) = FLOAT(ICP)
      XY(9) = DXh
      XY(8) = XMIN
C
C
C THIS SECTION SETS CERTAIN VARIABLES FOR THE CYLINDER CASE.
C AKA IS A CONSTANT USED IN THE SCATTERERING AND DELTA IS SET TO
C ZERO FOR A VERTICAL CYLINDER.
C
      IF(IDA .NE. 2) GO TO 25
      DELTA=F.
      AKA=W.I*A/2.
   25 CONTINUE
C
C
C THE INPUT ANGLES ARE CONVERTED TO RADIANS AND
C THEIR SINES AND COSINES ARE CALCULATED.
C
      ALPHA=ALPHA/RAD
      DELTA=DELTA/RAD
      COSD=COS(DELTA)
      SIND=SIN(DELTA)
      COSA=COS(ALPHA)
      SINA=SIN(ALPHA)
C
C
C BECAUSE OF CERTAIN APPROXIMATIONS MADE IN THE ANALYSIS
C THERE IS A LIMIT ON THE SIZE OF THE SCATTERERS THAT MAY
C BE SIMULATED.  TO AVOID THIS PROBLEM AS MUCH AS
C POSSIBLE, FOR THE RECTANGULAR SURFACE.
C THE PROGRAM WILL BREAK UP TOO LARGE A WALL INTO
C SMALLER PIECES.  TO AVOID PROBLEMS WITH OTHER TYPES
C OF SCATTERERS THE VARIABLES INVOLVED ARE SET TO DEFAULT
C VALUES AND THE BREAKING UP SECTION IS SKIPPED.
C
      IH=1
      IV=1
      DX=0.
      DY=0.
      DZ=0.
      DXZ=0.
      DYZ=0.
      IF(IDA .NE. 1) GO TO 25
C
C
C TEMP IS THE MAXIMUM DISTANCE FROM THE REFERENCE POINT ON THE
C WALL THAT WILL GIVE A REASONABLE ERROR IN THE APPROXIMATION.
C
      TEMP=SQRT(LAMBDA*SQRT((XXA(1)-XW(1))**2+(YA-XW(2))**2))/5.
C
```

```
C
C IH IS THE NUMBER OF PIECES HORIZONTALLY INTO WHICH THE WALL MUST BE
C DIVIDED.
C
      IH=IFIX(WW/2./TEMP)+1
C
C
C IV IS THE THE NUMBER OF PIECES VERTICALLY.
C
      IV=IFIX(HW/TEMP)+1
C
C
      WRITE(6,1013) ID,XW(1),XW(2),XW(3),ALPHA,DELTA,WW,HW,IH,IV
C WW AND HW ARE SET TO NEW VALUES, THESE ARE THE SIZES OF THE
C PIECES.  DX AND DY ARE THE CHANGE IN X- AND Y-COORDINATES BETWEEN
C PIECES IN THE HORIZONTAL ROWS.   DZ IS THE CHANGE IN ELEVATION
C BETWEEN ROWS VERTICALLY.  DXZ AND DYZ ARE THE CHANGE IN X AND Y
C BETWEEN ROWS.  THIS CHANGE OCCURS ONLY IN TILTED WALLS (SIND
C NOT EQUAL TO ZERO).
C
      AI=IH
      WW=WW/AI
      TEMP=WW*(AI-1.)/2.
      DX=ABS (COSA*WW)
      XW(1)=XW(1)-ABS(COSA*TEMP)
      DY=SIGN(SINA*WW,XW(2))
      XW(2)=XW(2)+SIGN((-SINA*TEMP),XW(2))
      HW=HW/FLOAT(IV)
      DZ=COSD*HW
      DXZ=SIND*HW*SINA
      DYZ=SIND*HW*COSA
      GO TO 27
C
C
C XW IS THE COORDINATE VECTOR USED FOR THE LOCATION OF THE
C REFERENCE POINT OF EACH PIECE OF THE WALL.  XW0 IS USED
C AS ORIGIN OF THE WALL.  AS EACH PIECE IS USED FOR THE
C SCATTERING  XW IS INCREMENTED.  XW0 IS USED TO RESET XW
C FOR LOOPING ON ROWS.
C
   26 WRITE(6,1013) ID,XW(1),XW(2),XW(3),ALPHA,DELTA,WW,HW
   27 XW0(1)=XW(1)-DX-DXZ
      XW0(2)=XW(2)-DY-DYZ
      XW0(3)=XW(3)-DZ
C
C
C THIS LOOP IS FOR THE ROWS
C
      DO 42 IB=1,IV
      XW0(1)=XW0(1)+DXZ
      XW0(2)=XW0(2)+DYZ
      XW0(3)=XW0(3)+DZ
      XW(1)=XW0(1)
      XW(2)=XW0(2)
      XW(3)=XW0(3)
C
```

```
C
C THIS LOOP IS WITHIN EACH ROW AND IS FOR HORIZONTALLY SEPARATED
C PIECES.
C
      DO 41 IA=1,IH
C
C
C XW IS THE COORDINATE VECTOR OF THE REFERENCE POINT ON THE
C PIECE BEING SIMULATTED.
C
      XW(1)=XW(1)+DX
      XW(2)=XW(2)+DY
C
C
C SUBROUTINE FLC IS USED TO CALCULATE THE FIELDS GENERATED BY THE
C ANTNNAE SYSTEM AT THE REFERENCE POINT.   AFTER THE CALL
C THE FIELDS AT THE REFERENCE POINT FOR ALL ANTENNAE ARE  IN
C EWR.
C
      CALL FLC(XW(1),XW(2),XW(3))
C
C THIS LOOP IS ON THE ANTENNAE.  FOR EACH PIECE THE PROGRAM
C CALCULATES THE SCATTERED FIELD FROM ALL ANTENNAE.
C IEL IS THE NUMBER OF THE ANTENNA BEING SIMULATED.
C
C
      DO 40 IEL=1,NEL
C
C
C XA,YA,HA ARE THE X-,Y- AND Z- COORDINATES OF THE
C ANTENNA.
C
      XA = XXA(IEL)
      HA=ZA(IEL)
C
C
C THIS SECTION INITIALIZES THE RECEIVER POINT
C LOCATION VARIABLES.  IR IS THE NUMBER OF THE RECEIVER POINT.
C
      IR=0
      IF(ICF.EQ.0) GO TO 29
      CDEG = XMIN - DXR
      GO TO 30
   29 XR = XMIN - DXR
   30 CONTINUE
      IF(MODE.GT.6) ZZ = ZA(IEL)
C
C
C DW IS THE HORIZONTAL DISTANCE FROM THE ANTENNA TO THE
C REFERENCE POINT.
C
      DW = SQRT((XW(1)-XA)**2 + (XW(2)-YA)**2)
C
C
C AN IS A VECTOR WHOSE COORDINATES ARE THE DIRECTION COSINES
C FROM THE REFERENCE POINT ON THE SURFACE  OF THE SCATTERER TO
```

```
C THE ANTENNA.  THE REFERENCE SYSTEM USED IS ALIGNED WITH
C THE SIDES OF THE RECTANGLE AND THE THIRD AXIS IS
C THE OUTWARD NORMAL.  IN THE CASE OF THE CYLINDER THE
C NORMAL IS ASSUMED TO LIE IN A HORIZONTAL PLANE AND
C TO POINT AT THE ANTENNA.
C
      IF(I7 .NE. 2) GO TO 32
      AN(1)=(XA-XW(1))/DW
      AN(2)=(YA-YW(2))/DW
      AN(3)=0.
      GO TO 33
   32 CONTINUE
      AN(1)=SINA
      AN(2)=-COSA
      AN(3)=0.
   33 CONTINUE
C
C
C THE HORIZONTAL ANGLE BEWTEEN THE NORMAL TO THE SURFACE AND
C THE LINE OF SIGHT TO THE ANTENNA IS GAMMA.  SING AND COSG
C ARE THE SINE AND COSINE OF GAMMA.
C
      COSG=(-AN(1)*(XW(1)-XA)-AN(2)*(XW(2)-YA))/DW
      SING = (-AN(2)*(XW(1)-XA) + AN(1)*(XW(2)-YA))/DW
C
C
C IF THE COSG IS NEGATIVE THEN THE LINE OF SIGHT IS
C THRU THE BACK OF THE SCATTERER AND THE ILLUMINATION OF
C THE FRONT SURFACE IS ASSUMED TO BE OF ZERO INTENSITY
C AND THE FIELD FROM THIS SCATTERING IS IGNORED.
C
      IF (COSG) 34,34,35
   34 WRITE (6,1017) IA,IB,IEL
      GO TO 40
   35 CONTINUE
C
C
C THIS IS THE LOOP BACK POINT FOR THE RECEIVER POINTS.
C FOR EACH PIECE OF SCATTERER AND FOR EACH ANTENNA
C THE PROGRAM CALCULATES ALL THE FIELDS AT ALL THE
C RECEIVER POINTS BEFORE GOING ON TO THE NEXT PIECE
C OR ANTENNA.  XR,YR, AND ZR ARE THE COORDINATES
C OF THE RECEIVER LOCATION. VX,VY AND VZ ARE THE
C VELOCITIES IN THOSE DIRECTIONS.  THE LOCATION
C IS DETERMINED BY SLIGHTLY DIFFERENT METHODS DEPENDING
C ON THE FLIGHT TYPE.  THE VALUE OF ICF IS THE CONTROL.
C IR IS THE RECEIVER POINT NUMBER AND IS USED TO
C DETERMINE WHERE THE FIELDS FROM THE SCATTERING
C ARE TO BE SUMMED.
C
   36 CONTINUE
      IF(ICF .LE. 0) GO TO 37
      CDEG=CDEG+DXR
      IF( (CDEG-XMAX)*DXR .GE. 0.) GO TO 40
      XR=R*COS(CDEG/RAD)
      YR=R*SIN(CDEG/RAD)
```

```
      VX = - VEL*YR/R
      VY =   VEL*XR/R
      VZ = 0.0
      GO TO 39
   37 CONTINUE
      XR=XR+DXR
      IF( (XR-XMAX)*DXR .GE. 0.) GO TO 40
      YR=XR*TANPR
      ZR = ZUP
       IF(XR .LT. XTH) GO TO 38
      ZR = ZR + (XR-XTH)*TANSR
      VZ = VEL*SPSI
      GO TO 39
   38 VZ = 0.0
   39 CONTINUE
      IF(IR .GT. 499) GO TO 40
      IR=IR+1
C
C
C RW IS THE DISTANCE FROM THE RECEIVER POINT TO THE
C SCATTERER REFERENCE POINT.
C
      RW=SQRT((XR-XW(1))**2+(YR-XW(2))**2+(ZR-XW(3))**2)
C
C
C RR IS THE HORIZONTAL DISTANCE FROM THE RECEIVER TO THE
C REFERENCE POINT.
C
      RR=SQRT((XR-XW(1))**2+(YR-XW(2))**2)
C
C
C BETA IS THE HORIZONTAL ANGLE BETWEEN THE SURFACE NORMAL AND
C THE LINE OF SIGHT TO THE RECEIVER POINT.  SINB AND COSB
C ARE THE SINE AND COSINE OF BETA.
C
      COSB=(AN(1)*(XR-XW(1))+AN(2)*(YR-XW(2)))/RR
      SINB=(-AN(2)*(XR-XW(1))+AN(1)*(YR-XW(2)))/RR
C
C
C DR IS THE DISTANCE FROM THE ANTENNA TO THE
C REFERENCE POINT ON THE SCATTERER.
C
      DR = SQRT((XR-XA)**2 + (YR-YA)**2 + (ZR-ZZ)**2 )
C
C
C THIS SECTION EVALUATES THE SCATTERING FROM THE SURFACE.
C THE COMPLEX VARIABLE ,FAC, REPRESENTS THE GAIN FACTOR
C FROM THE REFERENCE POINT ON THE SURFACE TO THE
C RECEIVER POINT.
C
C
C
C PHID AND PHIJD ARE THE RELATIVE FREQUENCY SHIFTS DUE TO DOPPLER
C EFFECT FROM THE AIRCRAFT VELOCITY.
C
      PHID = AK*(VX*(XR-XA) + VY*(YR-YA) + VZ*(ZR-ZZ))/DR
```

```
      PHIJD = AK*(VX*(XR-XW(1))+VY*(YR-XW(2))+VZ*(ZR-XW(3)))/RW
C
C
C THESE CONSTANTS ARE THE GAIN FACTORS FOR THE VARIOUS CROSSTALK
C CASES.
C
      UT=(PHIJD-PHID)*TA/2.
      SNCUC(1) = SINC(UT+W97T)**2
      SNCUC(2) = SINC(UT+W1541)**2
      SNCUT = SINC(UT)
      SNCUD = SINC(UT+W60T)
C
C
C THIS SECTION CALCULATES THE GAIN FOR THE ACTUAL
C SCATTERING.
C
      A=AK*(SIND*(COSG+COSB)+COSD*((XW(3)-HA)/DW+(XW(3)-ZR)/RR))
      B=A+2.*AK*HA*COSD/DW
      FAC=CEXP(CMPLX(0.,RW*AK))*((CEXP(CMPLX(0.,A*HW))-(1.,0.))/A-
     ,CEXP(CMPLX(0.,2.*AK*HA*XW(3)/DW))*(CEXP(CMPLX(0.,B*HW))-(1.,0.))
     ./B)
      FAC=FAC/RW
      B=B-A
      A=AK*(SIND*(COSG+COSB)+COSD*((XW(3)-HA)/DW+(XW(3)+ZR)/RR))
      B=B+A
      RWP=SQRT(RR*RR+(-ZR-XW(3))**2)
      FAC=FAC-(CEXP(CMPLX(0.,RWP*AK))*((CEXP(CMPLX(0.,A*HW))-(1.,0.))/A-
     .CEXP(CMPLX(0.,2.*AK*HA*XW(3)/DW))*(CEXP(CMPLX(0.,B*HW))-(1.,0.))
     ./B))/RWP
      FAC=-FAC*AK*WW*COSD/PI/2.
C
C
C ALL STATEMENTS FOR CALCULATING THE SCATTERING FROM RECTANGLES AND
C CYLINDERS ARE THE SAME WITH THE EXCEPTION OF THE FOLLOWING STEP.
C IDA IS ONE FOR THE RECTANGLE AND TWO FOR THE CYLINDER.
C
      IF(IDA .EQ. 1) FAC=FAC*COSB*SINC(AK*WW*(SING-SINB)/2.)
      IF(IDA .EQ. 2) FAC=FAC*BESF(AKA,COSB,SINB)/2.
C
C
C IF ID IS NEGATIVE THE GAIN IS TAKEN IN THE OPPOSITE
C SENSE.
C
      IF( ID .LT. 0) FAC=-FAC
C
C
C THE GAIN IS MULTIPLIED BY THE SIGNALS AT THE REFERENCE
C POINT TO GIVE THE SIGNALS AT THE RECEIVER.  THESE SIGNALS ARE COMPLEX
C MAGNITUDES.  EP IS THE SIDEBAND PORTION OF THE CARRIER
C PLUS SIDEBAND FOR THE COURSE ANTENNA AND EE THE SIDEBAND
C ONLY.  EM IS THE SIDEBAND PORTION OF THE CARRIER PLUS SIDEBAND
C FOR THE CLEARANCE AND EC THE SIDEBAND ONLY.
C
      EP = FAC*EWR(IEL,1)
      EE = FAC*EWR(IEL,2)
      EM = FAC*EWR(IEL,3)
```

```
      EC = FAC*EWR(IEL,4)
C
C
C THESE ARE THE COMPLEX PHASORS FOR THE SIGNALS AT THE RECEIVER
C POINT  FOR THE DIFFERENT ANTENNAE AND FREQUENCIES.
C THEY HAVE THE FOLLOWING SIGNIFICANCE:
C        SYMBOL  USAGE
C        ZJP     CARRIER FROM THE COURSE ANTENNA
C        ZJPC(1) 90 HZ SIDEBAND FOR COURSE
C        ZJPC(2) 150 HZ SIDEBAND FOR COURSE
C        ZJM     CARRIER FROM CLEARANCE
C        ZJMC(1) 90 HZ FROM CLEARANCE
C        ZJMC(2) 150 HZ FROM CLEARANCE
C
      ZJP = EP/CMPLX(CP,0.0)
      ZJPC(1) = EP - EE
      ZJPC(2) = EP + EE
      ZJM = EM/CMPLX(CM,0.0)
      ZJMC(1) = EM - EC
      ZJMC(2) = EM + EC
C
C
C SUBROUTINE VARCAL ADDS THE FIELDS TO THE FIELDS
C ACCUMULATED FOR THE ,IR,TH RECEIVER POINT.
C
      CALL VARCAL (IR)
C
C
C THE PROGRAM LOOPS BACK TO THE NEXT RECEIVER POINT.
C
      GO TO 36
   40 CONTINUE
   41 CONTINUE
   42 CONTINUE
C
C
C THIS IS THE TRANSFER BACK TO PICK UP THE
C NEXT SCATTERER OR CONTROL CARD.
C
      GO TO 21
C
C
C  AT THIS POINT THE PROGRAM HAS ACCUMULATED THE SCATTERED FIELDS
C AND HAS READ IN A CONTROL CARD TERMINATING THE RUN.
C THE PROGRAM WILL ADD IN THE DIRECT UNSCATTERED FIELD, BOTH
C DIRECTLY FROM THE ANTENNA AND REFLECTED FROM THE GROUND.
C THEN THE APPROPRIATE RECORDS WILL BE OUTPUT.
C
   43 CONTINUE
      IR=0
      SNCUT = 1.0
      SNCUD = 0.0
      SNCUC(1) = 0.
      SNCUC(2) = 0.
C
C
```

```
C FROM THIS STATEMENT THROUGH JUST BEFORE STATEMENT 51 IS
C THE LOOP ON RECEIVER POINT.  THE LOOPING IS DONE THE SAME
C AS THE SECTION FOLLOWING STATEMENT 35.
C
   44 IF(ICF .GT. 0) GO TO 46
      XR = XR + DXR
      IF( (XR-XMAX)*DXR .GE. 0. ) GO TO 51
      YR = XR*TANPR
      IF(XR .LT. XTH) GO TO 45
      ZR = (XR-XTH)*TANSR + ZUP
      VZ = VEL*SPSI
      GO TO 47
   45 VZ = 0.0
      ZR = ZUP
      GO TO 47
   46 CDEG = CDEG + DXR
      IF((CDEG-XMAX)*DXR .GE. 0. ) GO TO 51
      TEMP = CDEG/RAD
      XR = R*COS(TEMP)
      YR = R*SIN(TEMP)
   47 IR=IR+1
      CALL CLEAR(ZE,4)
C
C
C THIS CALL TO FLC CAUSES THE CALCULATION OF THE FIELD LEVELS
C AT THE RECEIVER POINT.
C
      CALL FLC(XR,YR,ZR)
C
C
C THIS IS THE LOOP FOR THE DIFFERENT ANTENNAE.  IEL IS THE
C ANTENNA NUMBER.  NEL IS TOTAL NUMBER OF ANTENNAE BEING
C USED.
C
      DO 49 IEL=1,NEL
C
C THIS SECTION CALCULATES THE FIELDS FOR THE VARIOUS SIGNALS
C AT THE RECEIVER POINT.
C
      HA = ZA(IEL)
      XA = XXA(IEL)
      RD=SQRT(RA(IEL)**2-(ZR-HA)**2)
      CE=CMPLX(RD/RA(IEL),0.)
      RD=2.*AK*HA*ZR/RD
      CE=CE*CMPLX(1.-COS(RD),-SIN(RD))
      DO 50 J = 1,4
      EWR(IEL,J)=EWR(IEL,J)*CE
   50 ZE(J)=ZE(J)+EWR(IEL,J)
      ZJP = EWR(IEL,1)/CMPLX(CP,0.0)
      ZJPC(1) = EWR(IEL,1) - EWR(IEL,2)
      ZJPC(2) = EWR(IEL,1) + EWR(IEL,2)
      ZJM = EWR(IEL,3)/CMPLX(CM,0.0)
      ZJMC(1) = EWR(IEL,3) - EWR(IEL,4)
      ZJMC(2) = EWR(IEL,3) + EWR(IEL,4)
C
C
```

```
C THIS CALL TO VARCAL ADDS THE FIELDS TO THE ONES ACCUMULATED
C FROM THE SCATTERERS.
C
      CALL VARCAL (IR)
   49 CONTINUE
C
C
C DETEC TAKES THE COMPLEX FIELD PHASORS AND EVALUATES
C THE COURSE DEVIATION INDICATION (CDI).  IR IS THE RECEIVER POINT
C NUMBER AND IS USED IN THE SUBROUTINE TO SELECT WHICH FIELDS
C ARE TO BE USED.  DF(IR) IS THE LOCATION IN THE ARRAY WHERE
C THE CDI IS TO BE PLACED.
C
      CALL DETEC (IR,DF(IR))
      IF(IR .GT. 499) GO TO 51
      GO TO 44
   51 CONTINUE
      XY(18)=FLOAT(IR)
      WRITE(6,1018) ID,NC,IR,ICF
C
C
C THIS SECTION OUTPUTS THE CDI ON UNIT 8.  THE OUTPUT IS A LABEL
C RECORD (MEMO), TWO RECORDS OF FLIGHT AND ANTENNA DESCRIPTION,
C AND THE CDI RECORDS.
C
      IF(ID .EQ. 0) MEMO(13)=ILBL(5)
      WRITE (8,1005) MEMO
      WRITE(8,1014) XY,ID,NC,ICF
      WRITE(8,1016) (DF(I),I=1,IR)
C
C IF THE ID IS NOT 0 THE FLOW IS TO STATEMENT 57 TO PROCESS
C THE ID VALUE FROM THE CONTROL CARD.  OTHERWISE THE SIGNAL
C STRENGTHS ARE OUTPUT.
C
      IF( ID .NE. 0 ) GO TO 57
C
C
C IX IS THE NUMBER OF SIGNAL TYPES THAT ARE TO BE OUTPUT.  TWO
C FOR SIMPLE ANTENNA SYSTEMS, FOUR FOR CAPTURE EFFECT.
C
      IX=4
      IF(NEL .EQ. 1) IX=2
C
C
C THESE LOOPS CALCULATE THE SIGNAL STRENGTHS.  THE VALUES ARE
C PLACED IN XXRY(I,J).  WHERE I IS THE RECEIVER POINT NUMBER AND
C J HAS THE FOLLOWING USAGE:
C        J        USAGE
C        1        CARRIER LEVEL FOR COURSE ANTENNA
C        2        SIDEBAND LEVEL FOR COURSE ANRENNA
C        3        CARRIER LEVEL FOR CLEARANCE
C        4        SIDEBAND LEVEL FOR CLEARANCE
C XXRY OCCUPIES THE SAME LOCATION IN CORE AS ZP AND ZM.
C
      DO 52 I=1,IR
   52 XXRY(I,1)=CABS(ZP(I))*0.2
```

```
      DO 53 I=1,IR
   53 XXRY(I,2)=CABS(ZPC(I,1)-ZPC(I,2))/2.
      DO 54 I=1,IR
   54 XXRY(I,3)=CABS(ZM(I))*0.2
      DO 55 I=1,IR
   55 XXRY(I,4)=CABS(ZMC(I,1)-ZMC(I,2))/2.
C
C
C THIS LOOP OUTPUTS THE APPROPRIATE NUMBER OF SIGNALS ON UNIT 8.
C THE LABEL RECORD FOR EACH CASE IS ALTERED SLIGHTLY AS EXPLAINED
C IN THE DATA STATEMENT FOR ILBL.
C
      DO 56 J = 1,IX
      MEMO(13)=ILBL(J)
      WRITE(8,1005) MEMO
      WRITE(8,1014) XY,ID,NC,ICF
   56 WRITE(8,1016) (XXRY(I,J),I=1,IR)
C
C
C THIS SECTION CONTROLS THE FLOW OF THE PROGRAM AFTER THE OUPUT
C FOR THE CASE IS FINISHED.  THE CONTROL IS BY THE VALUE OF THE
C ID READ IN ON THE LAST CONTROL CARD.  THIS ABSOLUTE
C VALUE OF ID IS IN IDA.  DEPENDING ON THE VALUE OF IDA THE
C PROGRAM LOOPS BACK AND READS IN THE NEXT DATA CARD FOR THE
C NEXTCASE TO BE RUN.  THE VALUE WILL CAUSE THE TRANSFER IN
C THE FOLLOWING:
C         IDA      NEXT TYPE OF CARD READ
C         0        MODE
C         3-10     SCATTERER
C         11-15    LABEL
C         16-20    MODE
C         21-50    COURSE WIDTH
C
   57 CONTINUE
      IF(IDA .EQ. 0) GO TO 1
      IF(IDA .LE. 10) GO TO 20
      IF(IDA .LE. 15) GO TO 14
      IF(IDA .LE. 20) GO TO 1
      IF(IDA .LE. 50) GO TO 6
   58 CONTINUE
      END FILE 8
      REWIND 8
      STOP
 1000 FORMAT (8F10.3)
 1001 FORMAT(I2,2X,6X,7F10.3)
 1002 FORMAT(5X,4HCLS=,F9.4)
 1003 FORMAT(9H0MODE =   2I4/10H FRQ =     F7.2/
     1  8H XTH =        F9.2/ 8H ZA =     3F9.2/
     2 8H XA =    3F9.2/14H COURSE WIDTH  F7.2,8H DEGREES   )
 1004 FORMAT (3X,13A6,A2)
 1005 FORMAT (13A6,A2)
 1006 FORMAT (7F10.0,2X,3I2)
 1007 FORMAT(6H0 VEL=,E11.4)
 1008 FORMAT(26H OVER 500 RECEIVER POINTS )
 1009 FORMAT(6H0XMIN=,E11.4,7H  XMAX=,E11.4,7H  DXR=,E11.4,7H  PHIR=,E11
     X.4,7H  PSIR=,E11.4,6H  XTH=,E11.4,5H ZUP=,E11.4)
```

```
1010 FORMAT(16H  STRUCTURE DATA)
1011 FORMAT(55H ID         XW            YH            ZW          ALPHA
    X,6HDELTA ,5X,23H  WW              HW        ,5X,1HH
    X,5X,13H V  SECTIONS  )
1012 FORMAT (I2,3F .0,5X,2F5.2,3F10.0)
1013 FORMAT (I3,1X,7E12.4,5X,I3,4X,I3)
1014 FORMAT(1X,7F18.9,/ 3F18.9,I10,10X,2I10)
1015 FORMAT(6H0MIND=,E11.4,7H  MAXD=,E11.4,7H  DDEG=,E11.4,4H  R=,
    XE11.4,7H   ZUP=,E11.4,7H   ICF=,I2)
1016 FORMAT( 7F15.8 )
1017 FORMAT(27H SURFACE IS NOT ILLUMINATED  ,
    X5H   H=,I2,5H   V=,I2,6H  IEL=,I2)
1018 FORMAT (2X,3HID= ,I3,5X,3HNC= ,I3,5X,3HIR= ,I3,5X,4HICF= ,I2,//)
     END
```

```
C
C
C THIS SUBROUTINE IS USED TO ZERO OUT THE CONTENTS OF
C VARIOUS MATRACIES.
C
      SUBROUTINE CLEAR (X,N)
      COMPLEX X(1)
      DO 1 I = 1,N
    1 X(I) = (0.,0.)
      RETURN
      END
```

```
C
C
C THIS SUBROUTINE IS USED TO INPUT DATA FOR CALCULATING THEORECTICAL
C PATTERNS FOR ARRAY TYPE ANTENNAE.
C
      SUBROUTINE CRRNTS( D, C, S, ET, NE )
      LOGICAL EOF
      DIMENSION ET(19),D(1)
       COMPLEX C(1),S(1)
      COMMON /SUB/ MODE,ICP,FRQ,LAMBDA,PI,RADD,PHI(3),PSI(3),NEL,XTH
      IF(EOF(5)) GO TO  3
      I = 1
C
C
C THIS IS THE INPUT FOR THE ELEMENT LOCATION AND CURRENT DESCRIPTION
C DT IS THE ELEMENT DISPLACEMENT IN THE Y-DIRECTION, MEASURED
C       IN WAVELENGTHS.
C CT IS THE CARRIER PLUS SIDEBAND AMPLITUDE, IN RELATIVE UNITS
C PC IS THE CARRIER PLUS SIDEBAND PHASE, IN DEGREES
C ST IS THE SIDEBAND ONLY AMPLITUDE, IN RELATIVE UNITS
C PS IS THE SIDEBAND ONLY PHASE, IN DEGREES
C
    1 READ (5,1000) DT, CT, PC, ST, PS
C
C THIS TEST IS TO SEE IF THE END OF THE ELEMENT CARDS HAS BEEN
C REACHED.  IF THE CARRIER PHASE IS GREATER THAN 500 FLOW
C IS TO THE ELEMENT PATTERN SECTION.
C
      IF( PC .GT. 500.) GO TO 2
C
C THIS IS THE 90 DEGREE PHASE SHIFT FOR THE QUADRATURE OF
C THE SIDEBAND ONLY TO THE SIDEBAND IN THE CARRIER PLUS SIDEBAND.
C
      PS = PS+90.0
      WRITE (6,1000) DT,CT,PC,ST,PS
      D(I) = DT*2.*PI
      C(I)=CT*CEXP(CMPLX(0.,PC*RADD))
      S(I) = ST*CEXP(CMPLX(0.,PS*RADD))
      I = I + 1
C
C
C THIS STATEMENT LOOPS BACK FOR THE NEXT ELEMENT IF THE TOTAL
C NUMBER OF ELEMENTS DOES NOT EXCEED THE AVAILABLE SPACE.
      IF( I .LT. 26) GO TO 1
C
C
C THIS SECTION READS IN THE PATTERN FOR THE ELMENTS. NE IS THE
C NUMBER OF ELEMENTS.  ALL ELEMENTS ARE ASSUMED TO HAVE THE SAME
C PATTERNS.
C
    2  NE = I - 1
C
C
C ET WILL CONTAIN THE ELEMENT PATTERN.  THE VALUES ARE IN
C RELATIVE AMPLITUDES.  ET(1) IS THE VALUE AT ZERO DEGEES AND
```

```
C SUCCESSIVE VALUES ARE AT 10 DEGREE SPACING UP TO 180.  THUS
C THERE ARE 19 POINTS GIVEN. THE PATTERN IS SYMETRIC ABOUT
C THE ZERO DEGREE POINT.
C
      READ (5,1000) ET
      WRITE(6,1000) ET
      RETURN
    3 WRITE(6,1001)
      END FILE 8
      STOP
 1000 FORMAT( 8F10.4 )
 1001 FORMAT (20H ARRAY DATA MISSING     )
      END
```

```
C
C
C THIS SUBROUTINE INPUTS THE ANTENNA PATTERNS FOR THE MEASURED
C PATTERN ANTENNA CASES.
C
      SUBROUTINE PATTRN ( ARAD, AFPP, AGPP )
      LOGICAL EOF
      DIMENSION ARAD(50), AFPP(52), AGPP(5P)
      DATA  RAD /  57.2957795  /
      IX = 1
      IF(EOF(5)) GO TO 4
    1 READ(5,1000) ANG, AFPP(IX), AGPP(IX)
      AFPP(IX)=AFPP(IX)*100022.
      AGPP(IX)=AGPP(IX)*103670.
      ARAD(IX)=ANG     /RAD
      IX=IX+1
      IF( IX .GE. 51) GO TO 2
      IF( ANG .LT. 361.) GO TO 1
      IF( IX .LE. 2) GO TO 4
    2 WRITE (6,1001)
      WRITE (6,1002)
      IY=IX-2
      DO 3 I=1,IY
      ANG=ARAD(I)*RAD+.00001
    3 WRITE (6,1003) ANG,AFPP(I),AGPP(I)
      GO TO 5
    5 RETURN
    4 WRITE (6,1004)
      END FILE 8
      STOP
 1000 FORMAT(8F10.0)
 1001 FORMAT(20H0ANTENNA PATTERN MEASUREMENT)
 1002 FORMAT(34H ANGLE READ    SIDEBAND    CARRIER)
 1003 FORMAT (3E12.4)
 1004 FORMAT(33H MEASURED ANTENNA PATTERN MISSING )
      END
```

```
C
C
C THIS SUBROUTINE SIMULATES THE BEHAVIOR OF THE ILS RECEIVER
C SYSTEM.  FOR THE IR,TH RECEIVER POINT IT CALCULATES THE CDI
C THAT WOULD BE OBSERVED WITH THE FIELD LEVELS IN ZP,ZM
C ZPC AND ZMC.
C
      SUBROUTINE DETEC (IR,CDI)
      DOUBLE PRECISION G000
      REAL N
      COMPLEX  ZP(500),ZPC(500,2),
     2         ZM(500),ZMC(500,2)
      DIMENSION VCD(500,2),VPD(500,2),VMD(500,2)
      DIMENSION V(2),G000(26)
      COMMON ZP,ZPC,ZM,ZMC,VCD,VPD,VMD
      COMMON /VAR/ SM,SNCUT,SNCUD,SNCUC(2),VPC(2),VMC(2)
      DATA NG /5/
      DATA G000/ .10000D+1,-.2500000D+00,
     1-.46875000000000D-01,-.19531250000000D-01,-.10681152343750D-01,
     1-.67291259765625D-02,-.46262741088867D-02,-.33752918243408D-02,
     1-.25710230693221D-02,-.20234903786331D-02,-.16339684807463D-02,
     1-.13470112062350D-02,-.11295250218950D-02,-.96076462661188D-03,
     1-.82718893235079D-03,-.71965437114518D-03,-.63180593716750D-03,
     1-.55911546169754D-03,-.49828577026285D-03,-.44656985629529D-03,
     1-.40302075164631D-03,-.36532323235967D-03,-.33267812946802D-03,
     1-.30422125733489D-03,-.27926560731914D-03,-.25725947746239D-03/
      CALL DTC(ZP(IR),VP,VPC)
      CALL DTC(ZM(IR),VM,VMC)
      BK2 = 4.0*VP*VM/(VP+VM)**2
      UW = VM/VP
      IF( UW .EQ. 0.) GO TO 2
      N = NG
      N1 = N + 1.
      CC = 0.0
      CP = 0.0
      CM = 0.0
    1 IF( N1 .LE. 0 ) GO TO 3
      G = G000(N1)
      CC = CC*BK2 + G
      CP = CP*BK2 + G*(1.+N*(UW-1.))
      CM = CM*BK2 + G*(1.+N*(1./UW-1.))
      N1 = N1 - 1
      N=N1-1
      GO TO 1
    2 CC= 1.0
      CP = 1.0
      CM = 0.0
    3 DO 4  I = 1,2
      VD2I = CP*CP*VPD(IR,I) + CM*CM*VMD(IR,I) + CC*CC*VCD(IR,I)
      VCI = CP*VPC(I) + CM*VMC(I)
    4 V(I) = SQRT( VCI*VCI  + VD2I )
      CDI = SM*(V(2)-V(1))/(V(2)+V(1))
      RETURN
      END
```

```
C
C
C THIS SUBROUTINE SIMULATES THE EFFECTS OF PHASE SHIFT BETWEEN
C CARRIER AND SIDEBANDS ON DETECTED 90 AND 150 HZ AMPLITUDE.
C
      SUBROUTINE DTC ( ZN,VN, VNC )
      COMPLEX ZN
      DIMENSION ZN(500,1),VNC(1)
      VN = CABS(ZN(1,1))
      PH = 0.0
      IF( VN .GT. 0.) PH = ATAN2(AIMAG(ZN(1,1)),REAL(ZN(1,1)))
      COSP = COS(PH)
      SINP=SIN(PH)
      DO 1  I = 1,2
    1 VNC(I) = COSP*REAL(ZN(1,I+1)) + SINP*AIMAG(ZN(1,I+1))
      RETURN
      END
```

```
C
C
C THIS SUBROUTINE ADDS THE FIELDS IN ZJP, ZJM, ZJPC, AND ZJMC
C TO THE SUMMATIONS IN ZPC, ZMC, VCD, VPD AND VMD.  THE ARRAYS
C CONTAIN THE COMPLEX SUMS FOR EACH RECEIVER POINT.  THE SYMBOLS
C HAVE THE FOLLOWING USAGE:
C         SYMBOL  USAGE
C         ZP        CARRIER FROM COURSE ANTENNA
C         ZM        CARRIER FROM CLEARANCE
C         ZPC(IR,1)        9Ø HZ SIDEBAND FROM COURSE
C         ZPC(IR,2)        15Ø HZ SIDEBAND FROM COURSE
C         ZMC(IR,1)        9Ø HZ SIDEBAND FROM CLEARANCE
C         ZMC(IR,2)        15Ø HZ SIDEBAND FROM CLEARANCE
C         VCD(IR,1)        *
C         VCD(IR,2)        *
C         VPD(IR,1)        * THESE ARE INTERNAL VARIABLES USED FOR
C         VPD(IR,2)        * DOPPLER EFFECTS.  THEY HAVE NO DIRECT
C         VMD(IR,1)        * PHYSICAL MEANING.
C         VMD(IR,2)        *
C
C SNCUT IS THE GAIN FACTOR FROM THE DIFFERENCE OF THE SCATTERED
C SIGNAL FROM THE DIRECT SIGNAL FREQUENCY.  THIS FREQUENCY
C SHIFT IS CAUSED BY THE DIFFERENT VELOCITIES OF THE AIRCRAFT
C RELATIVE TO THE ILS ANTENNA AND THE SCATTERERS. SNCUC(1) IS
C THE GAIN OF THE CROSS TALK FROM THE CARRIER THROUGH THE 9Ø HZ
C FILTER.  SINCUC(2) IS THE CROSS TALK AT 15Ø HZ.
C SNCUD IS THE CROSS TALK FACTOR BETWEEN THE 9Ø HZ AND 15Ø HZ
C SIGNALS FROM THE DOPPLER SHIFT.
C
      SUBROUTINE VARCAL (IR)
      COMPLEX Z
      COMPLEX  ZP(5ØØ),ZPC(5ØØ,2),
     2         ZM(5ØØ),ZMC(5ØØ,2)
      DIMENSION VCD(5ØØ,2),VPD(5ØØ,2),VMD(5ØØ,2)
      COMMON     ZP,ZPC,ZM,ZMC,VCD,VPD,VMD
      COMMON /VAR/ SM,SNCUT,SNCUD,SNCUC(2)
      COMPLEX ZJM,ZJP,ZJPC(2),ZJMC(2)
      COMMON /AB/ ZJM,ZJP,ZJPC,ZJMC
      CAB2(Z) = REAL(Z*CONJG(Z))
      ZP(IR) = ZP(IR) + ZJP
      ZM(IR) = ZM(IR) + ZJM
      DO 1 I=1, 2
      ZPC(IR,I) = ZPC(IR,I) + ZJPC(I)*SNCUT
      ZMC(IR,I) = ZMC(IR,I) + ZJMC(I)*SNCUT
      VCD(IR,I) = VCD(IR,I) + (CAB2(ZJP    ) + CAB2(ZJM    ))*SNCUC(I)
      J=3-I
      SNCUD2 = SNCUD*SNCUD
      VPD(IR,J) = VPD(IR,J) + CAB2(ZJPC(I)) *SNCUD2
    1 VMD(IR,J) = VMD(IR,J) + CAB2(ZJMC(I)) *SNCUD2
      RETURN
      END
```

```
C
C
C THIS SUBROUTINE CALCULATES THE ELECTRIC FIELDS FOR THE
C SIDEBANDS AT LOCATION (X1,Y,Z).  ARRAY E IS THE SAME AS
C ARRAY EWP IN THE MAIN PROGRAM.
C
      SUBROUTINE FLC(X1,Y,Z)
      COMPLEX E,F,FPP,GPP,C(25,2),S(25,2)
      COMMON/CD/ ARAD(50),AFPP(50),AGPP(50),BRAD(50),BFPP(50),BGPP(50)
      COMMON /SUB/ LC(2),FRQ,WANDA,PI,RADD,PHI,P(2),PSI,TT(2),NEL,XTH,
     1 XXA(3),YA,HA(3),RA(3)
      COMMON /ANT/ LOC,FPP(2),GPP(2),E(4,4),CHA(2),AS(2),D(25,2),C,S,
     2             ET(20,2),ND(2)
      AK=2.*PI/WANDA
      JA = 1
C
C
C THIS IS THE LOOP ON ANTENNA NUMBER.
C
      DO 1 J=1,NEL
      CALL CLEAR (FPP,4)
C
C
C LOC IS THE TYPE FOR ANTENNA ,J,
C
      LOC = LC(J)
C
C X IS THE DISTANCE FROM THE ANTENNA TO THE POINT.
C
      X = X1 - XXA(J)
      R=SQRT(X**2+Y**2+(Z-HA(J))**2)
      RA(J) = R
      PHI=ATAN2(Y,X)
      PSI = ATAN2(Z-HA(J),X)
      JA=1+150*(J-1)
      IF( LOC .LT. 4) CALL CSP
      IF(LOC .EQ. 5) CALL ANTP(FPP(J),GPP(J),ARAD(JA),AFPP(JA),AGPP(JA))
      IF(LOC .EQ. 7) CALL LNAR(FPP(J),GPP(J),PHI,D(1,J),C(1,J),
     .S(1,J),ET(1,J),ND(J))
      CONS = AK*R
C
C
C F IS THE COMPLEX GAIN FACTOR FOR THE TRANSMISSION LOSS FROM THE
C ANTENNA TO THE POINT.
C
      F = CEXP(CMPLX(0.,CONS))/R
      DO 1 JC=1,2
      JB=2*JC-1
C
C
C GPP IS THE SIGNAL LEVEL FOR THE SIDEBAND PORTION OF THE CARRIER
C PLUS SIDEBAND.
C
      GPP(JC)= GPP(JC)*AS(JC)
C
```

```
C
C FPP IS THE COMPLEX PHASOR FOR THE SIDEBAND ONLY.
C
      FPP(JC)=FPP(JC)*CWA(JC)*AS(JC)
      E(J,JB)=GPP(JC)*F
    1 E(J,JB+1)= FPP(JC)*F
      RETURN
      END
```

```
*IPFTC SUBR
C
C
C THIS SUBROUTINE GIVES FPP AND GPP AT ANGLE PHI BY SUMMING THE SIGNALS
C FROM THE ND ELEMENTS IN THE ARRAY.  THE PATTERN FOR THE
C ELEMENTS IS IN FT.  THE RELATIVE CARRIER PLUS SIDEBANDS AND
C SIDEBAND ONLY SIGNALS FED TO THE ELEMENTS ARE IN C AND S.
C
      SUBROUTINE LNAR (FPP,GPP,PHI,D,C,S,ET,ND)
      COMPLEX  FPP,GPP,C,S
       DIMENSION D(1),C(1),S(1),ET(1)
      SIPH=SIN(PHI)
      TEMP=ABS(PHI)/.1745329
      I=TEMP+1.
      A=I-1
      R=TEMP-A
      EPP=R*(FT(I+1)-ET(I))+ET(I)
      FPP=(0.0,0.0)
      GPP=(0.0,0.0)
      DO 1 J=1,ND
      GPP = GPP + C(J)*CEXP(CMPLX(0.,-D(J)*SIPH))
    1 FPP = FPP + S(J)*CEXP(CMPLX(0.,-D(J)*SIPH))
      GPP = EPP*GPP
      FPP = EPP*FPP
      RETURN
      END
```

```
C
C
C THIS ANTENNA SUBROUTINE GIVES FPP AND GPP FOR ANGLE PHI BY
C INTERPOLATION IN TABLES ANT AND ACP.  ANGLE PHI IS IN
C RADIANS.  THE SUBROUTINE WILL INTERPOLATE BETWEEN VALUES
C BRACKETTING TPHI.  IF PHI IS OUTSIDE THE RANGE OF THE TABLE
C THEN EXTRAPOLATION FROM THE LAST TWO VALUES WILL BE USED.
C
      SUBROUTINE ANTP (FPP,GPP,ANG,ANT,ACP)
      DIMENSION ANG(50), ANT(50), ACP(50)
      COMMON /SUB/ LC(2),FRQ,WAMDA,PI,RADD,PHI,P(2),PSI,T(2),NAR,XTH,
     1 XXA(3),YA,HA(3),RA(3)
      DO 1 I=2,50
      K=I
      IF(ANG(I) .GE. 6.3) GO TO 5
      IF(ANG(I)-PHI) 1,3,2
    1 CONTINUE
    2 FPP=ANT(K-1)+(ANT(K)-ANT(K-1))*(PHI -ANG(K-1))/(ANG(K)-ANG(K-1))
      GPP=ACP(K-1)+(ACP(K)-ACP(K-1))*(PHI -ANG(K-1))/(ANG(K)-ANG(K-1))
      GO TO 4
    3 FPP=ANT(K)
      GPP=ACP(K)
    4 RETURN
    5 K=K-1
      GO TO 2
      END
```

```
C
C
C THIS ANTENNA SUBROUTINE WILL EVALUATE FPP AND GPP FOR THE
C STANDARD ANTENNAE.  THE VALUE OF LOC WILL DETERMINE THE TYPE
C OF ANTENNA USED.  THE SIGNALS WILL BE CALCULATED AT ANGLE PHI.
C
      SUBROUTINE CSP
      REAL LAMDA
      COMMON /SUB/ LC(2),FRQ,WAMDA,PI,RADD,PHI,P(2),PSI,T(2),NAR,XTH
      COMMON /ANT/ LOC,FPP,XF,FPM,YF,GPP,XG,GPM,YG,E(4,4)
      DIMENSION C(10),S(10),D(10),ET(20)
      SIPH=SIN(PHI)
       GO TO (1,4,6),LOC
C
C
C THIS IS THE V-RING ANTENNA
C
    1 C0=2.221
      C(1)=1.030
      C(2)=0.546
      C(3)=0.385
      C(4)=0.275
      C(5)=0.214
      C(6)=0.175
      C(7)=0.148
      D(1)=186.9
      D(2)=497.4
      D(3)=786.8
      D(4)=1122.
      D(5)=1442.
      D(6)=1763.
      D(7)=2083.
      DO 2 J=1,7
    2 D(J)=D(J)*RADD
      ET(1)=1.00
      ET(2)=0.99
      ET(3)=0.97
      ET(4)=0.92
      ET(5)=0.84
      ET(6)=0.73
      ET(7)=0.62
      ET(8)=0.48
      ET(9)=0.33
      ET(10)=0.22
      ET(11)=0.13
      ET(12)=0.13
      ET(13)=0.18
      ET(14)=0.23
      ET(15)=0.30
      ET(16)=0.36
      ET(17)=0.38
      ET(18)=0.39
      ET(19)=0.40
      TEMP=ABS(PHI)/.1745329
      I=TEMP+1.
```

```
      A=I-1
      R=TEMP-A
      EPP=R*(ET(I+1)-ET(I))+ET(I)
      FPP=0.0
      GPP=C0*EPP
      DO 3 J=1,7
      CSPH=COS(D(J)*SIPH)
      SNPH=SIN(D(J)*SIPH)
      GPP = GPP + 2.*EPP*C(J)*CSPH
    3 FPP = FPP + 2.*EPP*C(J)*SNPH
      GO TO 8
C
C
C THIS IS THE 8-LOOP ANTENNA
C
    4 C(1)=1.29
      C(2)=1.03
      C(3)=0.58
      C(4)=0.33
      D(1)=55.3
      D(2)=190.0
      D(3)=500.0
      D(4)=900.0
      FPP=0.
      CSPH=2.*COS(RADD*D(1)*SIPH)
      GPP=C(1)*CSPH
      DO 5 J=2,4
      SNPH=2.*SIN(RADD*C(J)*SIPH)
    5 FPP=FPP+C(J)*SNPH
      GO TO 8
C
C
C
C THIS IS THE WAVEGUIDE ANTENNA
C
    6 C(1)=3.210
      C(2)=2.950
      C(3)=2.560
      C(4)=2.020
      C(5)=1.410
      C(6)=0.865
      C(7)=0.545
      C(8)=0.064
      C(9)=-0.16
      S(1)=0.179
      S(2)=0.513
      S(3)=0.776
      S(4)=0.994
      S(5)=1.000
      S(6)=0.962
      S(7)=0.893
      S(8)=0.783
      S(9)=0.543
      D(1)=117.
      D(2)=352.
      D(3)=587.
```

```
      D(4)=922.
      D(5)=1062.
      D(6)=1295.
      D(7)=1532.
      D(8)=1765.
      D(9)=2080.
      FPP=0.0
      GPP=0.0
      DO 7 J=1,9
      CSPH=2.*COS(RADD*D(J)*SIPH)
      SNPH=2.*SIN(RADD*D(J)*SIPH)
      GPP=GPP+C(J)*CSPH
    7 FPP=FPP+S(J)*SNPH
    8 RETURN
      END
```

```
C
C
C THIS FUNCTION EVALUATES THE WEIGHTED SUM OF A SERIES OF
C BESSEL FUNCTIONS.  IT IS USED TO CALCULATE THE SCATTERING
C FROM A CYLINDER.
C
      COMPLEX FUNCTION BESF(AKA,XCB,XSB)
      COMPLEX SUM
      DATA PI,EE/3.14159265,2.71828183/
      CB=XCB
      SUM=(-2.0,0.)
      IF(CB .LT. -.99996) GO TO 6
      SB=XSB
      I=(ABS(CB+SB)*8.+10.+AKA*1.3)/2.
      FM=I*2.
      CB2=SQRT((1.+CB)/2.)
      V=2.*AKA*CB2
      VI=2./V
      XI=3./V
      IF(V .LT. 3.) GO TO 1
      PHI=V-.78539816-XI*(.04166397+XI*(.00003954-XI*(
     ..00262573-XI*(.00054125+XI*(.00029333-XI*.00013558)))))
      FO=.79788456-XI*(.00000077+XI*(.00552740+XI*(
     ..00009512-XI*(.00137237-XI*(.00072805-XI*.00014476)))))
      BJ=FO*COS(PHI)/SQRT(V)
      GO TO 2
    1 XI=V*V/9.
      BJ=1.-XI*(2.2499997-XI*(1.2656208-XI*(.3163866-XI*(
     ..0444479-XI*(.0039444-XI*(.00021))))))
    2 RI=-SB*SIN(AKA*SB)/(AKA*(1.+CB))+2.*CB2*CB2*BJ
      SER=0.
      FN=FM+10.
      EJ=((1.-1./FN)**(FN-.5))*EE*V/2./FN
      OJ=1.
      FN=FN-1.
    3 FJ=-EJ+FN*VI*OJ
      AM=ABS(FJ)+ABS(OJ)
      EJ=OJ/AM
      OJ=FJ/AM
      FN=FN-1.
      IF(FN .GT. FM-.5) GO TO 3
      B=ATAN2(SB,CB)
      S1=SIN((FN+2.)*B/2.)
      C1=COS((FN+2.)*B/2.)
      S2=S1*CB-C1*SB
      C2=C1*CB+S1*SB
    4 YI=FN
      ZI=FN+2.
      SER=SER+EJ*(C2/YI-C1/ZI)
      IF(FN .LT. 2.) GO TO 5
      C1=C2
      S1=S2
      TEMP=C2*CB+S2*SB
      S2=S2*CB-C2*SB
      C2=TEMP
```

```
      FJ=-EJ+FN*VI*OJ
      EJ=OJ
      OJ=FJ
      FN=FN-1.
      FJ=-EJ+FN*VI*OJ
      AM=ABS(OJ)+ABS(FJ)
      FN=FN-1.
      SER=SER/AM
      EJ=OJ/AM
      OJ=FJ/AM
      GO TO 4
    5 AJ=-EJ+FN*VI*OJ
      OJ=OJ*BJ/AJ
      SER=SER*BJ/AJ
      RI=RI-2.*CB2*SER
      CI=-PI*CB2*OJ
      SUM=CMPLX(RI,CI)
    6 BESF=SUM
      RETURN
      END
```

```
C
C
C
C THIS IS THE SINC FUNCTION.  IT IS DEFINED AS THE SINE OF
C X DIVIDED BY X.  SINC OF ZERO IS TAKEN TO BE ONE.
C
      FUNCTION SINC(X)
      XX=ABS(X)
      IF(XX .LT. .0001220703) XX=.0001
      SINC=SIN(XX)/XX
      RETURN
      END
```

```
BLOCK DATA
COMPLEX ZJM,ZJP,ZJPC(2),ZJMC(2)
COMMON /AB/ ZJM,ZJP,ZJPC,ZJMC
COMMON /VAR/ SM,SNCUT,SNCUD,SNCUC(2),VPC(2),VMC(2)
COMMON /SUB/DUMMY(4),PI,RADD
COMMON /ANT/DUM(43),AS(2)
DATA AS/1.0,1.0/
DATA SM/387./
DATA ZJM,ZJP,ZJPC,ZJMC /4*(0.,0.)/
DATA PI,RADD/3.14159265,.017453292/
END
```

APPENDIX B

DYNAMIC SIMULATION

PROGRAM DYNM LISTING

The ILSLOC program calculates the CDI at each point in space; this CDI includes the Doppler effects from the velocity of the aircraft. In the simulation, the receiver system is assumed to generate the CDI value instantaneously. In the real case, the inertia of the electrical and mechanical portions of the system limit the rate of change of the CDI. Thus the real observed CDI appears to have been low-pass filtered from the instantaneous CDI.

The program DYNM takes the output tape generated by program ILSLOC and converts it to observed CDI by simulating the effect of a low-pass filter. The variable TAU is the time constant of the effective filter.*

Note: When a flight path has been segmented, the low-pass filter will operate continuously over the entire flight path.

```
$IBFTC MAIN
C THIS PROGRAM SIMULATES THE EFFECT OF THE  MECHANICAL AND ELECTRICAL
C INERTIA OF THE ILS RECEIVER ON THE CDI.  THIS EFFECT IS EQUIVALENT
C TO A SIMPLE R-C LOW PASS FILTER.  THE VARIABLE TAU IS THE TIME
C CONSTANT OF THE EFFECTIVE FILTER.  A TYPICAL VALUE IS .4 SECONDS.
C THE INPUT TAPE IS ON UNIT 11, THE OUTPUT ON UNIT 12.
C
C
      DIMENSION XY(10),DEF(501),MEMO(14)
      LOGICAL EOF
      DATA ILBL/4HDYNM/
      DATA TAU/0.4/
      IF(EOF(11)) GO TO 4
    1 IT=0
      DELC=0.
    2 READ(11,1000) MEMO,XY,ID,NC,ICF
      WRITE(6,1003) MEMO,XY,ID,NC,ICF
      DEFK=ABS(XY(9)/XY(5)/TAU)
      IR=IFIX(XY(10)+.1)
      READ(11,1001) (DEF(I),I=1,IR)
      IF(IT .EQ. 0) CEF2=DEF(1)
      IT=1
      DO 3 I=1,IR
      CEF2=CEF2+DELC
      DELC=(DEF(I)-CEF2)*DEFK
    3 DEF(I)=CEF2
      MEMO(13)=ILBL
      WRITE(12,1000) MEMO,XY,ID,NC,ICF
      WRITE(12,1001) (DEF(I),I=1,IR)
      IF(ID .GT. 13) GO TO 1
      IF( ID .EQ. 0) GO TO 1
      GO TO 2
    4 REWIND 11
      END FILE 12
      REWIND 12
      CALL EXIT
 1000 FORMAT(13A6,A2,/,1X,7F18.9,/,3F18.9,I10,10X,2I10)
 1001 FORMAT(7E15.8)
 1003 FORMAT(1X,13A6,A2,/,1X,7F18.9,/,3F18.9,I10,10X,2I10)
      STOP
      END
```

APPENDIX C

ILSPLT PLOTTING ROUTINE

This program has been written to generate graphs of the static and dynamic CDI's. It was written on the IBM 7094 using the CALCOMP plotting subroutines.

The first input card has the following format:

Col.	Symbol	Usage
1-2	NL	Number of lines per graph
3-4	NGRFS	Number of graphs
5-7	NTAPE (1)	Input logical unit no. for first line
8-10	NTAPE (2)	Input logical unit no. for second line
11-13	NTAPE (3)	Input logical unit no. for third line

NL permits the overlaying of two or more CDI or signal strength graphs for comparison purposes. The scaling will be set by the first graph, and the successive overlays will be plotted to the same scale. A maximum of three lines per graph will be allowed.

NGRFS sets the maximum number of graphs to be drawn. Each graph will have the same number of overlays.

NTAPE (i) gives the logical unit number used for the input of the ith line on each graph. If the value of NTAPE is negative then its absolute value will be used as its logical unit number and the tape will be rewound before input.

The second input card defines the scaling used for the graph (or graphs) described above. It has the following format:

Col.	Symbol	Usage
1-10	XSC	Horizontal scale in ft./in. or deg./in
11-20	DELX	Tick mark spacing in ft. or deg.
21-30	YMAX	Maximum y-value on vertical scale
[illegible]	YMIN	Minimum y-value on vertical scale
41-50	DELY	Tick mark spacing on vertical spacing in microamps for CDI or relative units

The horizontal axis is drawn in either feet or degrees per inch as specified by XSC. The tick mark spacing along the axis is determined by DELX. The length of the axis will be adjusted to the shortest length with an integral number of tick marks that will cover the domain required by the input data. When a flight path has been segmented it is treated as a single line on the graph.

YMAX, YMIN define the range of the plotted variable: CDI or relative signal strength. The Y-axis has a fixed length of seven inches. If DELY does not integrally divide the range, DELY will be adjusted to yield an integer. When the range (YMAX-YMIN) is zero, the program will automatically scale the range to the largest scale that will include the data in the length of the axis.

When multiple graphs are plotted, each graph is scaled independently.

After all NGRFS graphs have been drawn, the program will loop back to the beginning and attempt to read in a new NL card. This allows many graphs to be drawn. If the user wishes to replot data using different scales or overlaid with different sets of data, he may use the negative NTAPE to rewind the input tape.

The program will terminate after reaching an end-of-file on the card input unit.

The vertical scale on the graph is always labeled "microamperes". This is valid only for CDI graphs. All others are in relative units and this labeling should be ignored.

```
      COMMON/TEST/XMIN,DXR,NTOT,NP
      LOGICAL EOF
      DIMENSION IBUF(1000)
      DIMENSION NTAPE(3),MEMO(14),M(14)
      EQUIVALENCE (M(1),MEMO(1))
      COMMON /PDF/ DF(2000),XLEN,NSTEPS,IDEF,IDENT,DX(10),NPTS(10)
      COMMON /PRINT/ NL,XSC,DELX,YMAX,YMIN,DELY,ICF
      CALL PLOTS(IBUF,1000)
      CALL PLOT(0.0,-12.,-3)
      CALL FACTOR (0.4)
      ILBL=1
   60   CONTINUE
      IF(EOF(5)) GO TO 55
      READ(5,100) NL,NGRFS,NTAPE
      WRITE(6,100) NL,NGRFS,NTAPE
      IF(NGRFS.LE.0) NGRFS=3
100   FORMAT(2I2,3I3)
      DO 401 I=1,NL
      IF(NTAPE(I).GE.0) GO TO 401
      NTAPE(I)=-NTAPE(I)
      NU=NTAPE(I)
       REWIND NU
401   CONTINUE
      READ(5,101) XSC,DELX,YMAX,YMIN,DELY
      WRITE(6,101) XSC,DELX,YMAX,YMIN,DELY
  101 FORMAT(8F10.0)
      TEMP=AMIN1(YMIN,YMAX)
      YMAX=AMAX1(YMIN,YMAX)
      YMIN=TEMP
      TEMP=YMAX-YMIN
       IF(TEMP .NE. 0.) DELY=TEMP/(FLOAT(IFIX(TEMP/DELY+.5)))
      NPLT = 1
      NP = 1
      I = 1
      N1 = 1
      NTOT = 0
   10 NU = NTAPE(NP)
      IF(EOF(NU)) GO TO 50
      READ(NU,500) M,X0,DXR,XY,ID,IDEF,IDENT,ICF
      IF(ICF .NE. 0) ICF=1
      WRITE(6,600) MEMO,X0,DXR,XY,ID,IDEF,IDENT,ICF
      IF(ILBL .NE. 1) GO TO 70
      ILBL=0
      CALL SYMBOL(0.,0.,.14,MEMO,90.,80)
      CALL PLOT(3.,0.,-3)
70      CONTINUE
      IR =IFIX( XY+.1)
      NTOT = NTOT + IR
      IF(I.EQ.1) XMIN = X0
  500 FORMAT(13A6,A2,/,/,3F18.9,4I10)
  600 FORMAT(2X,13A6,A2,/,3F18.9,4I10)
501      FORMAT(7E15.8)
502      FORMAT(1X,7E15.8)
      READ(NU,501)(DF(J),J=N1,NTOT)
      WRITE(6,502) (DF(J),J=N1,NTOT)
```

```
      WRITE(6,1000) XMIN,IR,N1,NTOT,NP,I
 1000 FORMAT(F10.0,5I10)
      NPTS(I) = IR
      DX(I) = DXR
      IF( ID .GT. 13 ) GO TO 40
       IF(ID .EQ. C) GO TO 40
      N1 = N1 + IR
      I = I + 1
      GO TO 10
   11 NL = NP
   40 CONTINUE
      NSTEPS = I
      IF(NP.GT.1) GO TO 41
      CALL GRAPH2(0)
      GO TO 42
41      CALL GRAPH2(1)
   42 CONTINUE
      N1 = 1
      I = 1
      NTOT = 0
      IF(NP.EC.NL) GO TO 45
      NP = NP + 1
      GO TO 10
   45 NP = 1
      CALL PLOT(XLEN+7.,-12.,-3)
      NPLT = NPLT + 1
      ILBL=1
      IF(NPLT.GT.NGRFS) GO TO 60
      GO TO 10
   50 CONTINUE
      IF(NTOT.GT.0) GO TO 11
      CALL PLOT (XLEN+7.,-12.,-3)
      GO TO 60
   55 CONTINUE
      CALL PLOT(0.,0.,999)
      DO 400 I=1,NL
      NU=NTAPE(I)
400    REWIND NU
      STOP
      END
```

```
      SUBROUTINE GRAPH2(ITL)
      DIMENSION XLAB(4)
      COMMON/TEST/XO,DELTAX,NDELTA,NP
      DATA XLAB/24HDISTANCE,FT.  DEGREES      /
      DIMENSION TYPE(3)
      DIMENSION X(3),NC(3)
      COMMON /POF/ DF(2000),XLEN,NSTEPS,IDEF,IDENT,DX(10),NPTS(10)
      COMMON /PRINT/ NL,XSC,DELX,YMAX,YMIN,DELY,ICF
      DATA X /-5.,5.,5./
      DATA NC /1,5,4/
      IF(ITL .NE. C) GO TO 1
      ELX=DELX
      IF(DELTAX.LT.0.) ELX = -ABS(DELX)
       RANGE=0.
      DO 11 I=1,NSTEPS
11     RANGE=RANGE+FLOAT(NPTS(I))*DX(I)
      TIX=IFIX(RANGE/ELX+.9)
7     XLEN = ABS(ELX/XSC*TIX)
      IF(XLEN .GT. 40.) GO TO 9
      IF(XLEN .GT. 5.) GO TO 6
    9 XSC=ABS(RANGE/20.)
      XLEN=ABS(ELX/XSC*TIX)
      WRITE(6,8) XSC
8      FORMAT(25H AXIS OUT OF RANGE SCALE=,E12.5,8H FT./IN.  /)
6     CONTINUE
      XMAX=TIX*ELX+XO
      XMIN = AMIN1(XO,XMAX)
      XMAX = AMAX1(XO,XMAX)
      ND = 2
      PWR = 0.
      CALL PLOT(0.,1.5,-3)
      AMIN=YMIN
      AMAX=YMAX
      IF(YMAX .EQ. YMIN) CALL SCLAX(7.,DF,NDELTA,AMAX,AMIN,DELY,ND,PWR)
      CALL AXIS3(0.,0.,AMAX,AMIN,DELY,7.,12HMICROAMPERES,12,ND,PWR,DELN)
      YSC = DELN
      IXLAB=2*ICF+1
      IXSC=-1
      IF(ABS(ELX) .LT. 10.) IXSC=1
      CALL AXIS3(0.,0.,XMAX,XMIN,ELX,-XLEN,XLAB(IXLAB),12 ,IXSC,0.
     .,DELN)
      XSC = DELN
      XT = XLEN/2. - 2.
      IF(AMIN*AMAX.GT.0.) GO TO 2
      IF( AMIN .EQ. 0.) GO TO 2
      ZERO=(0.-AMIN/10.**PWR)/YSC
      CALL PLOT (0.,ZERO,3)
      CALL PLOT(XLEN,ZERO,2)
2     CONTINUE
1      CONTINUE
      XI=0.
      IF(DELTAX .LT. 0.) XI=XMAX-XMIN
      J=1
      DO 5 I=1,NSTEPS
      DELTAX = DX(I)
```

```
      NX=NPTS(I)
      IF(I .LT. NSTEPS) NX=NX+1
       YM=AMIN/10.**PWR
      CALL XCLINF(XI,DELTAX,DF(J),NX,0.,XSC,YM,YSC,NC(NP))
      J=J+NPTS(I)
      XI=XI+DX(I)*FLOAT(NPTS(I))
    5 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE XCLINE(XI,DX,Y,N,XM,DELX,YM,DELY,NC)
      DIMENSION Y(1),IPEN(4)
      REAL L(4,4),LL(4)
      DATA IPEN/2,3,2,3/
      DATA L/.3,.1,.3,.1,.5,3*.05,.3,3*.1,.1,.05,.1,.05/
      X = XI
    2 IC = NC - 1
      XP1 = (X-XM)/DELX
      YP1=(Y(1)-YM)/DELY
      CALL PLOT(XP1,YP1,3)
      IF(IC.LE.0) GO TO 1000
      IF(IC.GT.4) IC = 4
      K=1
      I=2
      X = X + DX
      XP2 = (X-XM)/DELX
      YP2=(Y(2)-YM)/DELY
    1 LL(K)=L(K,IC)
   10 DIFFX=XP2-XP1
      DIFFY=YP2-YP1
      DIS=SQRT(DIFFX*DIFFX+DIFFY*DIFFY)
      IF(DIS.GT.LL(K))GO TO 100
      CALL PLOT(XP2,YP2,IPEN(K))
      XP1=XP2
      YP1=YP2
      I=I+1
      IF(I.GT.N)RETURN
      X = X + DX
      XP2 = (X-XM)/DELX
      YP2=(Y(I)-YM)/DELY
      LL(K)=LL(K)-DIS
      GO TO 10
  100 RATIO=DIS/LL(K)
      XP1=XP1+DIFFX/RATIO
      YP1=YP1+DIFFY/RATIO
      CALL PLOT(XP1,YP1,IPEN(K))
      K=K+1
      IF(K.EQ.5)K=1
      GO TO 1
 1000 DO 50 I=2,N
      X = X + DX
      XP1 = (X-XM)/DELX
      YP1=(Y(I)-YM)/DELY
   50 CALL PLOT(XP1,YP1,2)
      RETURN
      END
```

```
      SUBROUTINE SCLAX(AINCH,VAR,N,VMAX,VMIN,DELTA,ND,EXP)
      DIMENSION VAR(1)
C
      AXLEN = AINCH
      VMAX = VAR(1)
      VMIN = VAR(1)
      DO 40 I=2,N
      VMAX = AMAX1(VMAX,VAR(I))
   40 VMIN = AMIN1(VMIN,VAR(I))
      ND = 0
      NE = 0
      M = 2
      TOTAL = VMAX - VMIN
C                             DETERMINE EXPONENT AND INCREMENT/INCH
      VM = AMAX1(ABS(VMAX),ABS(VMIN))
      IF(VMAX*VMIN) 6,5,7
    7 VAV = ABS(VMAX+VMIN)/2.
      DELTA = TOTAL/AXLEN
      IF(TOTAL.GT.0..AND.TOTAL/VM.LT..75) GO TO 4
      IF(VMAX.EQ.VM) VMIN=0.
      IF(VMIN.EQ.-VM) VMAX=0.
      GO TO 5
    6 AXLEN = AXLEN*VM/TOTAL
    5 DELTA = VM/AXLEN
      VAV = VM/2.
C                             TEST FOR VAV BETWEEN .01 AND 1000.
    4 IF(VAV.LE.1.E-11) GO TO 21
      IF(VAV - .01) 3,10,1
   41 IF(VAV - 1.) 3,10,10
    1 IF(VAV - 1000.) 10,2,2
C                             VAV GE 1000.
    2 IF(NE.EQ.0) VAV = VM
      VAV = VAV/1000.
      NE = NE - 3
      GO TO 1
C                             VAV LT 1.
    3 VAV = VAV*1000.
      NE = NE + 3
      GO TO 41
C                              DETERMINE DECIMAL PLACES IN DELTA
   10 IF(DELTA.LT.VM/1.E4) GO TO 21
      DELTA = DELTA*10.**NE
   11 IF(DELTA - 1.) 12,19,13
   12 DELTA = DELTA*10.
      ND = ND + 1
      GO TO 11
   13 IF(DELTA - 10.) 15,8,14
   14 DELTA = DELTA/10.
      ND = ND - 1
      GO TO 13
C                              DELTA NOW BETWEEN 1 AND 10
   15 IF(DELTA - 5.) 16,17,17
   16 IF(DELTA - 2.) 19,18,18
   17 DELTA = 5./10.**(ND+NE)
      GO TO 20
```

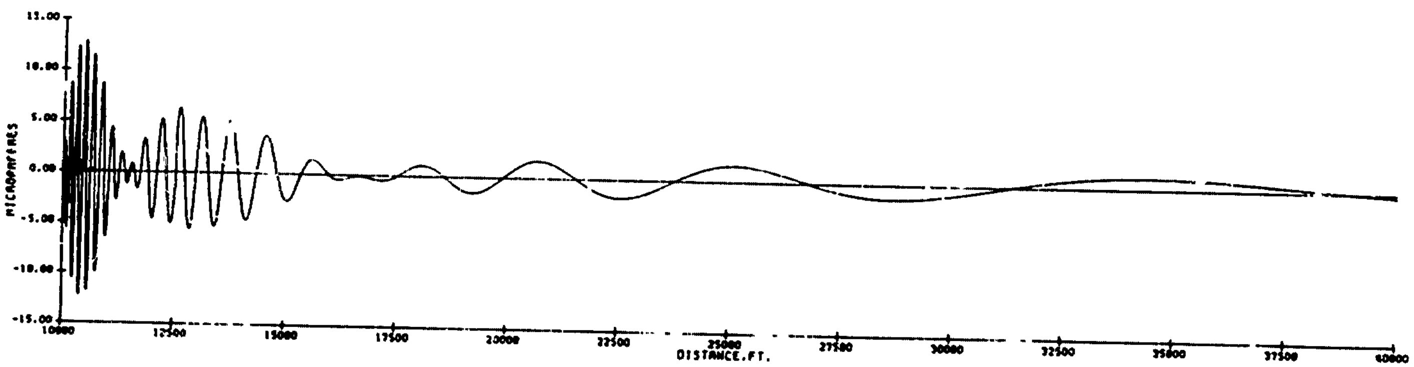
```
   18 DELTA = 2./10.**(ND+NE)
      M = 5
      GO TO 20
    8 ND = ND - 1
   19 DELTA = 1./10.**(ND+NE)
C                                     RESET VMIN (FIRSTV) FOR AXIS
   20 AK = VMIN/DELTA + .01
      K = (IFIX(AK)/M)*M
      IF(VMIN.LT.0.) K=K-M
      VMIN = DELTA*FLOAT(K)
      NDIV = (VMAX - VMIN)/DELTA + .9
      IF(FLOAT(NDIV).GT.AINCH*2.) DELTA=DELTA*AMAX1(2.,FLOAT(M)/2.)
      IF(ND.LE.0) ND = -1
   21 EXP = NE
      WRITE(6,1002) VMAX,VMIN,DELTA,ND,NE
      RETURN
 1002 FORMAT(1H0,3E13.3,3I7//)
      END
```

```
      SUBROUTINE AXIS3(X0,Y0,VMAX,VMIN,DELV,AINCH,BCD,NCR,NDEC,PWR,VSC)
      FACTOR = 10.**PWR
      AMIN = VMIN*FACTOR
      AMAX = VMAX*FACTOR
      DELX = ABS(DELV)*FACTOR
      DIMENSION BCD(1)
      HT = .15
      W1=0.
      W2=0.
      W3 = 0.
      NEXP = 0
      NCH=IABS(NCR)
      IF(PWR.NE.0.) NEXP = 6
      CINCH=ABS(AINCH)
      IF((VMAX-VMIN)/AMAX1(VMAX,-VMIN).LT.1.E-6) GO TO 50
      IF((AMAX-AMIN)/(DELX+1.E-8).GT.3.*CINCH) DELX = (AMAX-AMIN)/CINCH
      IF(DELX.GT.AMAX-AMIN) DELX = AMAX - AMIN
      IF(NCR.LT.0) W3 = 1.
      NUM=(AMAX-AMIN)/DELX+1.9
      ANC=CINCH/FLOAT(NUM-1)
      IF(AINCH.LT.0.)GO TO 5
      W2=1.
      GO TO 10
    5 W1=1.
   10 CALL PLOT(X0,Y0,3)
      VSC = DELX/FACTOR/ANC
      ANUM=AMIN-DELX
      X=0.
      Y=0.
      XM=0.
      OFF = .05
      DO 40 I=1,NUM
      ANUM=ANUM+DELX
      II=0
   25 IF(ABS(ANUM)/10.**II.LT.1.)GO TO 20
      II=II+1
      GO TO 25
   20 IF(ANUM.LT.0.)II=II+1
      IF(ABS(ANUM).LT.1.) II=II+1
      IMORE=NDEC+1
      II=II+IMORE
      IF(IFIX(W1)*I.EQ.1) HT = AMIN1(HT ,ANC/FLOAT(II+2))
      HL = AMAX1(.12,1.2*HT)
      CENTER = FLOAT(II)*HT/(1.+W1)
      XC = X - CENTER - W2*.15
      IF(XC.LT.XM) XM = XC
      IF(W2*W3.GT.0.) XC = .15
      IF(ABS(XC).GT.ABS(XM)) XM = XC
      YC = Y - W1*(HT + .15 - W3*(HT+.3)) - W2*OFF
      CALL PLOT(XC+X,Y0+Y,2)
      CALL PLOT(X0+X+.1*W2,Y0+Y+.1*W1,3)
      CALL PLOT(X0+X-.1*W2,Y0+Y-.1*W1,2)
      CALL NUMBER(X0+XC,Y0+YC,HT,ANUM,0.,NDEC)
      CALL PLOT(X0+X,Y0+Y,3)
      X=X+ANC*W1
```

AX3 - EFN SOURCE STATEMENT - IFN(S) -

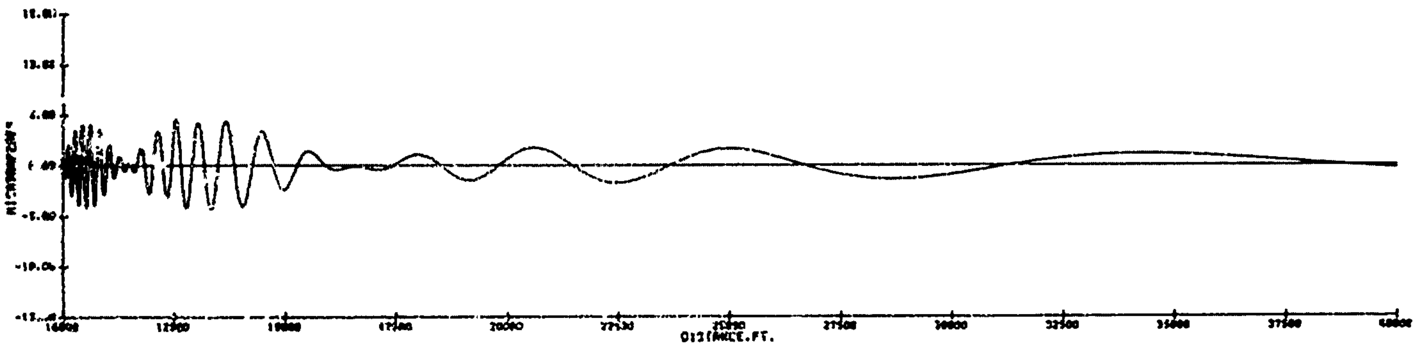
```
    Y=Y+ANC*W2
 40 CONTINUE
    BST = (CINCH - FLOAT(NCH+NEXP)*HL)/2.
    IF[illegible].1.) XM = -XM
    [illegible](XO + BST) + W2*(XO + XM - OFF + W3*(2.*OFF+HL))
    [illegible](YO + YC - 1.5*HL + W3*(HT + 2.*HL)) + W2*(YO+BST)
    [illegible]OL(XXC,YYC,HL,BCD,90.*W2,NCH)
    [illegible].EQ.0.) RETURN
    CALL SYMBOL(999.,999.,HL,5H * 10,90.*W2,5)
    X = 999. + (XXC-.65*HL-999.)*W2
    Y = 999. + (YYC+.66*HL-999.)*W1
    CALL NUMBER(X,Y,.75*HL,PWR,90.*W2,-1)
    RETURN
 50 VSC = (VMAX-VMIN+1.E-6/FACTOR)/CINCH
    WRITE(6,1000)
1000 FORMAT(1H0,27HINSUFFICIENT RANGE FOR AXIS )
    RETURN
    END
```

SIMULATED CERTIFICATION FLIGHT for
TEST CASE AIRPORT - GIVING
INSTANTANEOUS CDI USING MEASURED
A.FORD ANTENNA

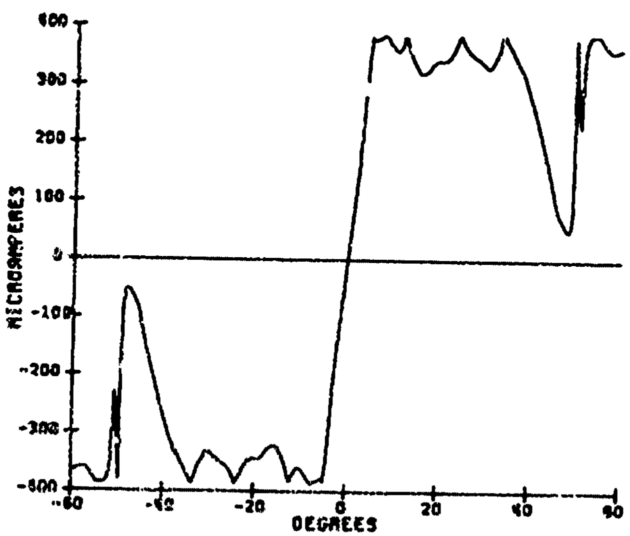


THIS IS A DEMONSTRATION CASE OF : STRAIGHT LINE FLIGHT

SIMULATED TEST FLIGHT SHOWING EFFECTS
of DYNAMIC SIMULATION - ASSUMED TIME
CONSTANT of .4 SECONDS



SIMULATED CLEAPANCE RUN for MEASURED PATTERN
ALFORD 14/6



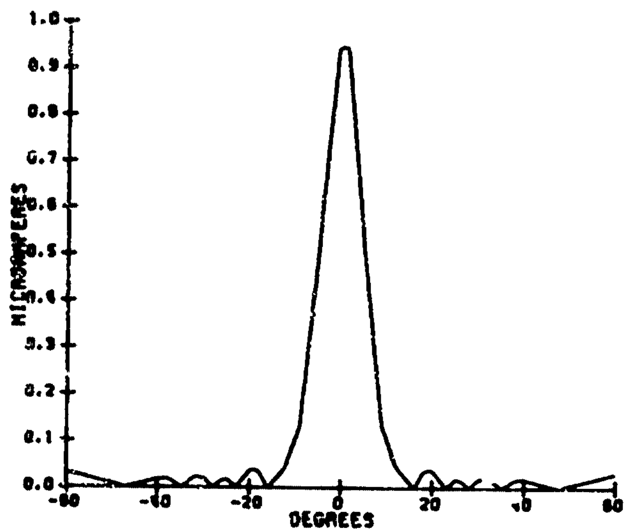
103

THIS IS THE CLEARANCE RUN WITHOUT SCATTERERS

MEASURED ANTENNA PATTERN - CARRIER and SIDEBAND for ALFORD 14, SCALE in RELATIVE UNITS

C CM

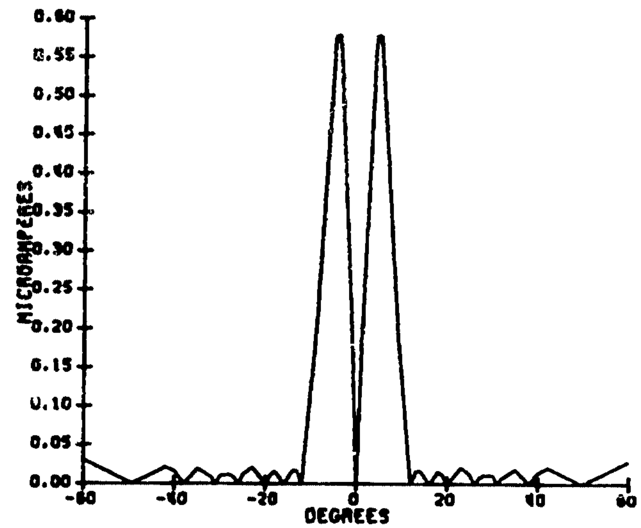
THIS IS THE CLEARANCE RUN WITHOUT SCATTERERS



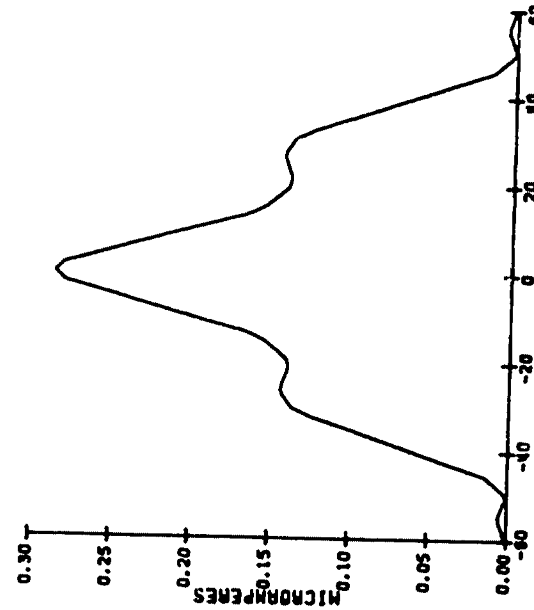
SIDEBAND ONLY for ALFORD 14

S CM

THIS IS THE CLEARANCE RUN WITHOUT SCATTERERS



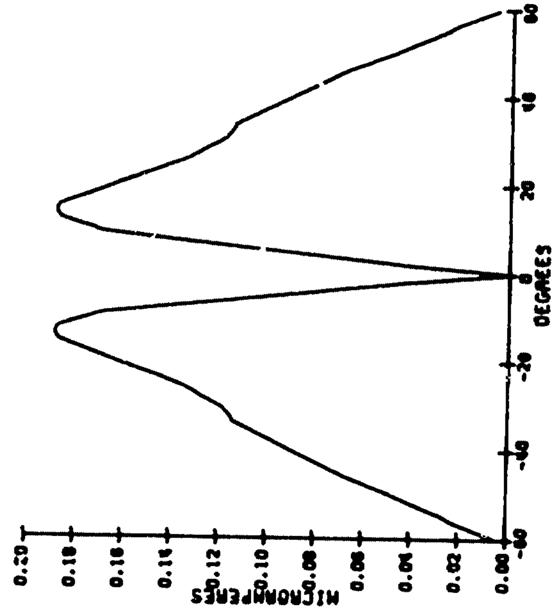
MEASURED ANTENNA PATTERN -
CARRIER and SIDEBAND for
ALFORD 6, SCALE in RELATIVE
UNITS



THIS IS THE CLEARANCE RUN WITHOUT SCATTERERS

C CL

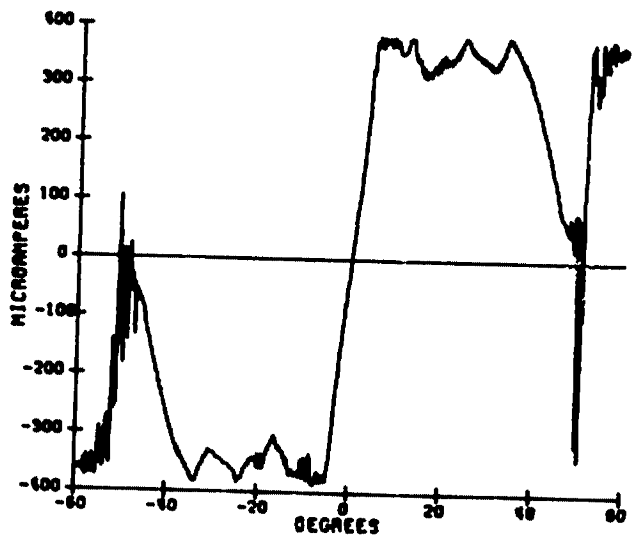
SIDEBAND ONLY for ALFORD 6



THIS IS T1.2 CLEARANCE RUN WITHOUT SCATTERERS

S CL

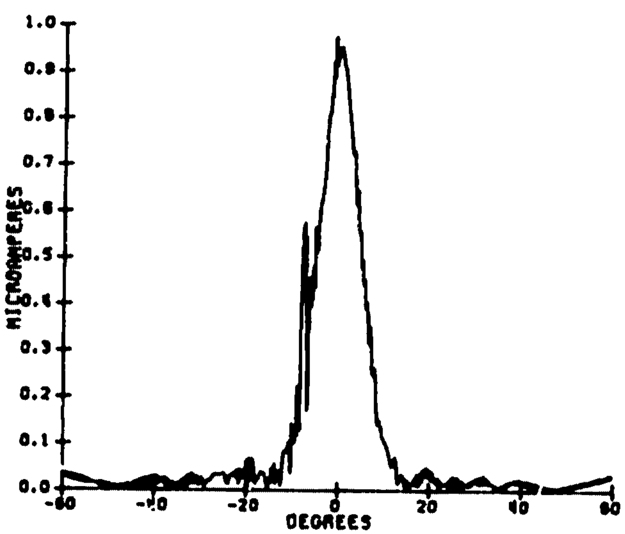
SIMULATED CLEARANCE RUN for TEST CASE AIRPORT ˉHOWING EFFECT of SCATTERERS ON CDI



This is Orbit Case with Scatterers

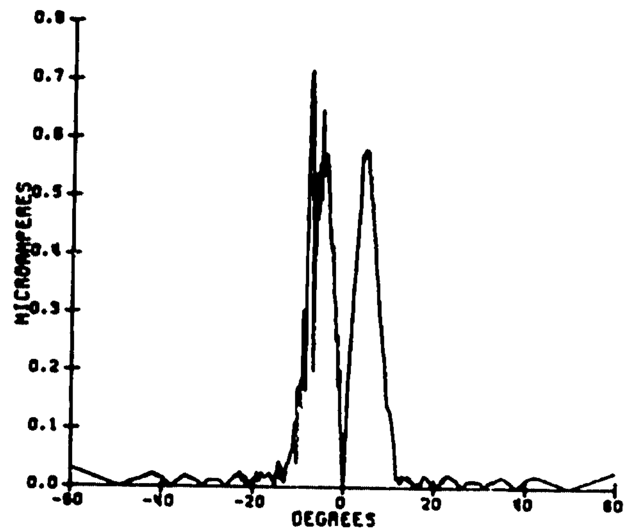
MEASURED ANTENNA PATTERN CARRIER
and SIDEBAND for ALFORD 14
SHOWING SCATTERERS, SCALE IN
RELATIVE UNITS

This is Orbit Case with Scatterers c cm



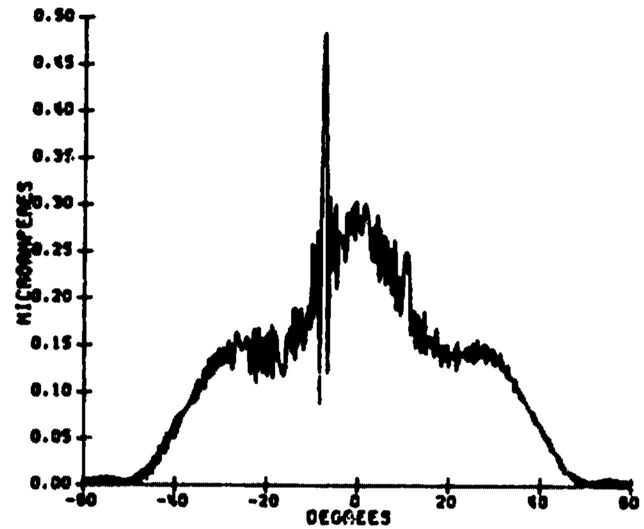
SIDEBAND ONLY - WITH SCATTERERS
for ALFORD 14

This is Orbit Case with Scatterers s cm



MEASURED ANTENNA PATTERN - CARRIER and SIDEBAND ONLY for ALFORD 6 SHOWING SCATTERERS, SCALE IN RELATIVE UNITS

This is Orbit Case with Scatterers



SIDEBAND ONLY SHOWING SCATTERERS for ALFORD 6

This is Orbit Case with Scatterers